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STRIP-MINE RECLAMATION

IN

APPALACHIA

Mined-Area Reclamation Research Unit
Northeastern Forest Experiment Station
Berea, Kentucky

July 1971

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This state-of-the-art report was prepared by the staff of our reclamation research work unit in respose to a request from a Congressional committee. However, the report finally submitted to the committee was greatly condensed from this.

Plans were to revise this and put it into shape for publication by the Station. This has not yet been done but it may be accomplished sometime in the future.

K. G. Reinhart

Reclamation Programs 19

a. Basic Reclamation 20
b. Reclamation for Productive Use 21

RECLAMATION PRE-PLANNING 23

Comprehensive Land Use Plans 23

Individual Mining Plans 24

COAL-HAUL AND MINE-ACCESS ROADS 26

a. Haul Road Design Criteria and Standards 28
b. Haul Road Route Location 29
c. Drainage Control 30
d. Roadway Cross Section Shape and Dimensions 31
e. Travelway Strength and Durability 32
f. Maintenance 33
g. Abandonment or Disposition of Mine Roads After Completion of the Mining Operation 35
h. A New Approach Needed 36

TABLE OF CONTENTS

STRIP-MINE RECLAMATION IN APPALACHIA

INTRODUCTION 1

The Appalachian Coal Field 2

a. Location and Physiography 2
b. Coal 3
c. Forests 6
d. Precipitation and Streamflow 7

Surface Mining 9

a. Methods 9
b. Effects on the Environment 13
c. Legislation and Controls 18

Reclamation Programs 19

a. Basic Reclamation 20
b. Reclamation for Productive Use 21

RECLAMATION PRE-PLANNING 23

Comprehensive Land Use Plans 23

Individual Mining Plans 24

COAL-HAUL AND MINE-ACCESS ROADS 26

a. Haul Road Design Criteria and Standards 28
b. Haul Road Route Location 29
c. Drainage Control 30
d. Roadway Cross Section Shape and Dimensions 31
e. Travelway Strength and Durability 32
f. Maintenance 33
g. Abandonment or Disposition of Mine Roads After Completion of the Mining Operation 35
h. A New Approach Needed 36

MINING AND SPOIL HANDLING 38

Mining Processes: Current Methods of Excavation and Overburden Handling 39

a. Single Seam; Single Cut 39
b. Single Seam; Multi-Cut 39
c. Multi-Seam; Single Cut 40
d. Multi-Seam; Multi-Cut 40
e. Auger Mining 40
f. Mountaintop Stripping 41

Reclamation Spoil Handling and Site Grading 42

a. Mined Site Conditions 42
b. Goals of Reclamation Grading 43
c. Grading and Spoil Handling Methods 44
d. Original Contour; Back Filled 49
e. Highwall Reduction 50
f. Mountaintop; Rolling Grade 51
g. Valley-Fill 51
h. Coordinating Operations 54

EROSION CONTROL AND WATER QUALITY 55

Prior to Mining 56

a. Silt Basins 56
b. Scalping 58

During Mining 58

During Reclamation 60

a. Backsloping 61
b. Bench Drainage 61
c. Impoundments 62
d. Diversion 63
e. Terraces 64
f. Vegetation 64
g. Soluble Salts 65

REVEGETATION 67

a. Purpose 67

Spoil Properties Affecting Plant Establishment 67

a. Chemical 67
b. Physical 69
c. Biological 70
d. Classification of Spoil 72

Improving Problem Spoils 73

Establishing Herbaceous Vegetation 77

a. Adaptation of Species 77
b. Herbaceous Mixtures 81
c. Methods of Establishment 83

Planting of Trees and Shrubs 87

a. Species 87
b. Methods of Establishment 89
c. Combination Plantings of Woody and Herbaceous Materials. 90

RECLAMATION FOR SPECIAL USES 93

a. Woodlands 93
b. Wildlife 94
c. Agriculture 96
d. Lakes and Recreation 98
e. Sanitary fill 99
f. Housing and Industrial Sites 100

RECLAMATION OF ABANDONED OR ORPHAN AREAS 101

RECOMMENDATIONS FOR APPLYING RECLAMATION TECHNIQUES AND DEVELOPING IMPROVED METHODS 103

Applying Known Techniques 103

a. In the Planning Stage 103
b. During the Mining Operation 104
c. During Reclamation 105

Research Needs 106

a. In the Planning Stage 106
b. During the Mining Operation 106
c. During Reclamation 107

STRIP-MINE RECLAMATION IN APPALACHIA

INTRODUCTION

Increasing demands for low-cost coal have expanded strip-mining operations in the Appalachians as a method for harvesting this resource. Operations are being conducted on thousands of acres of forested watersheds each year, resulting in the production of millions of tons of spoil-bank material. This material causes both chemical and sediment pollution of much-needed downstream water supplies; it damages timber, recreation, wildlife, and range resources on mountainous terrain. Furthermore, the spoil banks are unsightly, adversely affecting the aesthetics of the areas in which they occur, and often affecting the economic status of the communities in the area.

The electric power shortage is becoming ever more critical, and the demand for surface-mined coal is more likely to expand than decrease. We need coal as an energy source, but we also need to protect our environment from permanent damage. Thus the Forest Service is trying to develop practicable methods of reducing damage to forest resources during surface-mining operations and of restoring these resources after mining. This report summarizes the knowledge concerning reclamation that the Forest Service as well as other agencies and individuals have accumulated through research and practical experience.

The Appalachian Coal Field

The natural wealth found in Appalachia includes its rivers, soils. forests, and minerals, Much of the soil is too poor to support a vigorous agriculture. About two-thirds of the land surface is wooded; nearly all of this qualifies as commercial forest. The resource of greatest economic value over much of the territory, however, consists of deposits of minerals; by far the most important of these is coal. Development of natural resources cannot be separated from development of human resources. This is especially true in Appalachia where proper management of its natural wealth offers hope of improving the economic and social well-being of its people.

Location and Physiography

The Appalachian Region, as defined in Public Law 89-4 (1965), extends over parts of a 12-state area from New York to Alabama and covers about 185,000 square miles. The main physiographic feature is the Appalachian Mountain chain which runs northeast from central Alabama in a long, narrow, curving band. Its plateaus contain one of the world's largest and most valuable fuel reserves. The exploitable coal beds occur mainly in the Pennsylvanian rocks and generally range from a few feet to twelve feet in thickness.

The Appalachian plateaus are a high upland dissected by many incised wandering stream courses. The area is carved into small, steep-sided hills. Slopes of 45 degrees or more are common, and steep slopes prevail along the

major rivers. Most of the underlying rock strata are of the Mississippian and Pennsylvanian ages. The formations typically are repetitious sequences of shale, siltstone, limestone, and sandstone. The mineral fuels are also of sedimentary origin, having been deposited along with the enclosing sedimentary rocks.

We are directly concerned here only with that part of Appalachia underlain by coal. Coal deposits occur in approximately 50,000 square miles of the region and are in nine of the twelve states (Fig. 1). The bituminous coal basin extends uninteruptedly from northern Pennsylvania to western Alabama, a distance of 800 miles. It is 175 miles wide at the widest part in Pennsylvania and Ohio, and 35 miles wide at the narrowest part in Tennessee.

The anthracite region, located in Pennsylvania, is quite different from the bituminous region. The rocks are almost everywhere tilted at moderate to steep angles, and in places the beds are overturned. This area has a long history of mining, and much more of the surface (about 25 percent) has been disturbed. It is also more densely populated, and many of the mined areas lie close to population centers.

Coal

Coal is a sedimentary rock formed by the accumulation, alteration, and compaction of plant remains in a reducing environment similar to that found in swamps. During the Pennsylvanian time, conditions were conducive to coal formation. It has been estimated that a foot of coal contains plant materials accumulated over centuries.

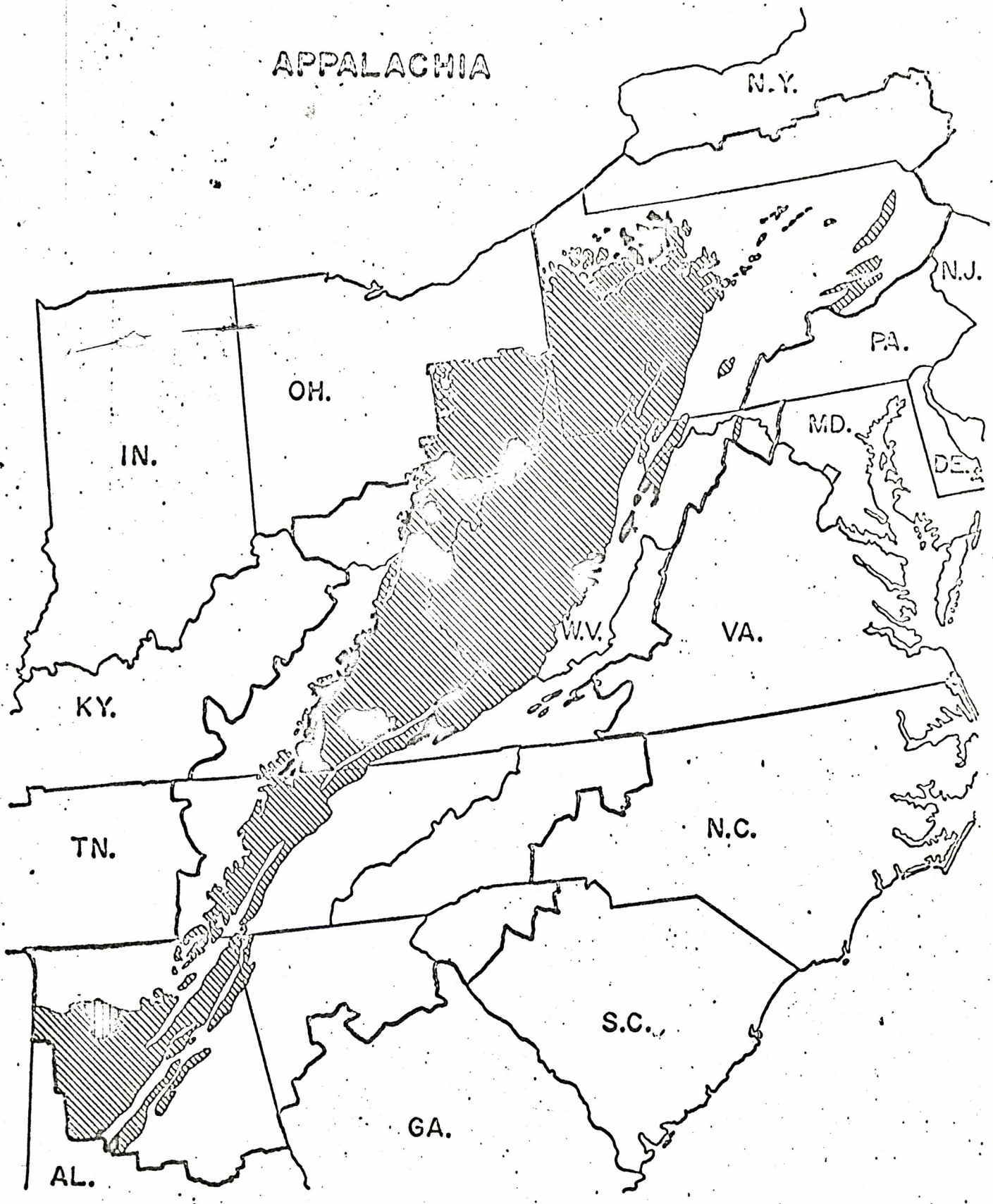

Figure 1.--Location of Coal Deposits
National Forest Land Underlain by Coal (in black)

Coal-bearing rocks were uplifted and folded by tangential pressures that were strongest from the southeast. Besides the heavy folding in the Anthracite Region, the east edge of the Appalachian bituminous coal basin dips about 20 degrees but may be locally very steep. Dips decrease gradually farther to the west, becoming almost negligible on the west edge of the basin. This variation in structure is paralleled by variation in volatility of the coal, volatility increasing from east to west. Low-volatile coal is selected for the manufacture of coke while high-volatile coal is used primarily in the electric utility industry.

Coal is essential to an industrial economy. It is used in the manufacture of steel and as a raw material in a wide variety of chemical products. As an energy fuel, coal serves a large market. In spite of competition from nuclear power plants, an increase in coal production will be necessary to meet future energy requirements as the population expands. Low stockpiles of coal and the closing of many small deep-mines unable to meet federal safety standards were major factors in the 1970 power crisis. Coal prices soared, and the major coal-producing states reported a large increase in strip-mine operations.

It is estimated that the recoverable reserves are sufficient for at least 300 years at the present rate of use. Although the supply is abundant, coal mining is an extractive mineral industry; thus the eventual decline of production in any area is certain.

Forests

Next to coal, the most important natural resource in Appalachia is the forest. In places the forest has given way to town and city development and to farming, but two-thirds of the 118 million acres in Appalachia are still in forest. It has been estimated that 90 percent of the surface mining was or is being conducted on forested watersheds.

The Appalachian forests are largely hardwood, and most can be classified as commercial. Over most of the area they are made up of a mixture of species which is determined by such factors as soil, elevation, slope, and aspect.

Most of the commercial forest land is in private ownership. Some of the larger holdings are under management by wood-using industries. The bulk of the private holdings are in small woodlots which are managed poorly, if at all. Of the public forest acreage, national forests include a far larger area than all other public lands combined. National forest land covers 13 percent (over 4 million acres) of the Appalachian coal fields (Fig. 1). The national forests are scientifically managed to achieve multiple-use objectives.

Mineral rights follow the same complicated ownership pattern as the timberlands. Mining companies seldom own much of the land they mine, and even small operations may involve surface and mineral rights of several landowners. On much of the public land, the government does not own the mineral

rights. Thus, the two major natural resources of Appalachia, coal and timber, are closely related. Strip mining has a tremendous impact on forested watersheds, and minimizing damage during mining and restoring disturbed land to production after mining is of prime importance in multiple-use management concepts.

Precipitation and Streamflow

Precipitation averages 47 inches annually and provides an adequate supply of water for the region. It is reasonably well distributed throughout the year, and its pattern is influenced largely by the topography. In addition there is a general north-south orientation to the pattern of precipitation, with a steady increase from about 35 inches in Pennsylvania to more than 55 inches in Alabama. Snowfall ranges from about 100 inches annually in the north to less than 3 inches in Alabama. Elevation is a major factor influencing amount of snowfall in any locality.

Of the 47 inches of annual precipitation, 20 to 30 inches leaves the region as surface runoff. Water moves seaward along well-developed stream systems (Fig. 2). Streams throughout the region experience low flows during early fall. In the spring, however, they are predisposed to severe flooding. The mountainous terrain induces both high precipitation and rapid runoff.

The quality of water in streams varies with the amount of runoff as well as with land and water-use patterns. The chamical quality of a stream is determined by the principal dissolved constituents in the water. Acid

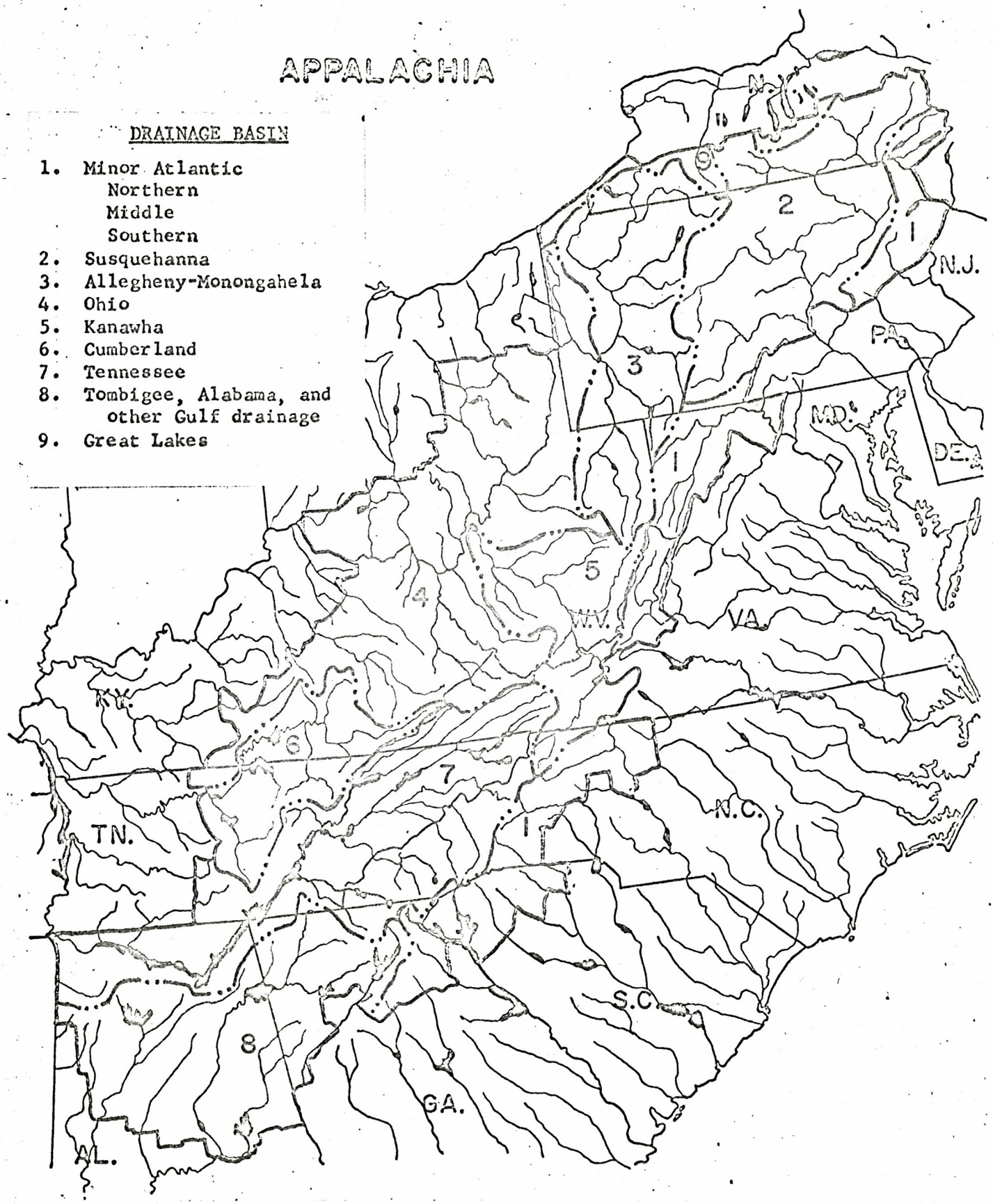

Figure 2.--Drainage Basins in the Appalachian Region

water draining from coal mines can produce erratic and extreme changes in dissolved-solids concentration of the receiving streams.

Water quality in streams is also influenced by suspended material or sediment loads. High sediment concentrations are detrimental to water resource development. Turbid water requires treatment before use for most purposes, lowers recreation potential of streams and lakes, and reduces storage capacity of reservoirs. Sediment deposits in stream channels reduce capacity and thus increase flooding.

Appalachia has been blessed with an abundant supply of good water. Surface mining has already seriously affected water quality and poses an even more serious threat to this most valuable natural resource in the future.

Surface Mining

Methods

"Surface mining" is the processes by which minerals are uncovered from the surface of the earth and then extracted. Although there are a number of different methods employed to recover minerals through surface operations, we are concerned here primarily with strip mining for coal. In Appalachia, strip mining may be further broken down as area stripping and contour stripping.

Area stripping is usually practiced on relatively flat terrain. The overburden, which may be more than a hundred feet thick, is loosened with

explosives and then removed by power shovels, draglines, or other types of excavators. The first cut is a long trench or "box cut" stretching across the area to be mined. The exposed coal is then removed and an adjacent cut is made, the spoil from it being dumped into the previous cut. The final cut, bounded on one side by the last spoil bank and on the other by the undisturbed highwall, often fills with water if left open.

Contour stripping predominates in the mountains of the Appalachian coal field. This method consists of removing the overburden above the coal bed by starting at the outcrop and proceeding along the hillside. After the coal is exposed and removed in this first cut, additional cuts may be made. Width of cuts varies according to steepness of slope and the amount of rock in the overburden, the range being generally 30 to 100 feet. The worked-out pit consists of a relatively flat floor bounded on the upper side by a highwall and on the downhill side by a rim below which there is frequently a precipitous downslope that has been covered by spoil material cast down the hillside (Fig. 3). In some areas there may be several contour strips on the same mountainside, one above the other. Over 70 percent of all contour mining operations are on slopes that exceed 11 degrees (20%); on the average, about 28-30 acres per linear mile are disturbed.

Auger mining is usually a supplement to contour stripping. When the overburden is too deep for further removal, huge augers may be used to bore into the exposed beds for further recovery of coal. The coal flows out

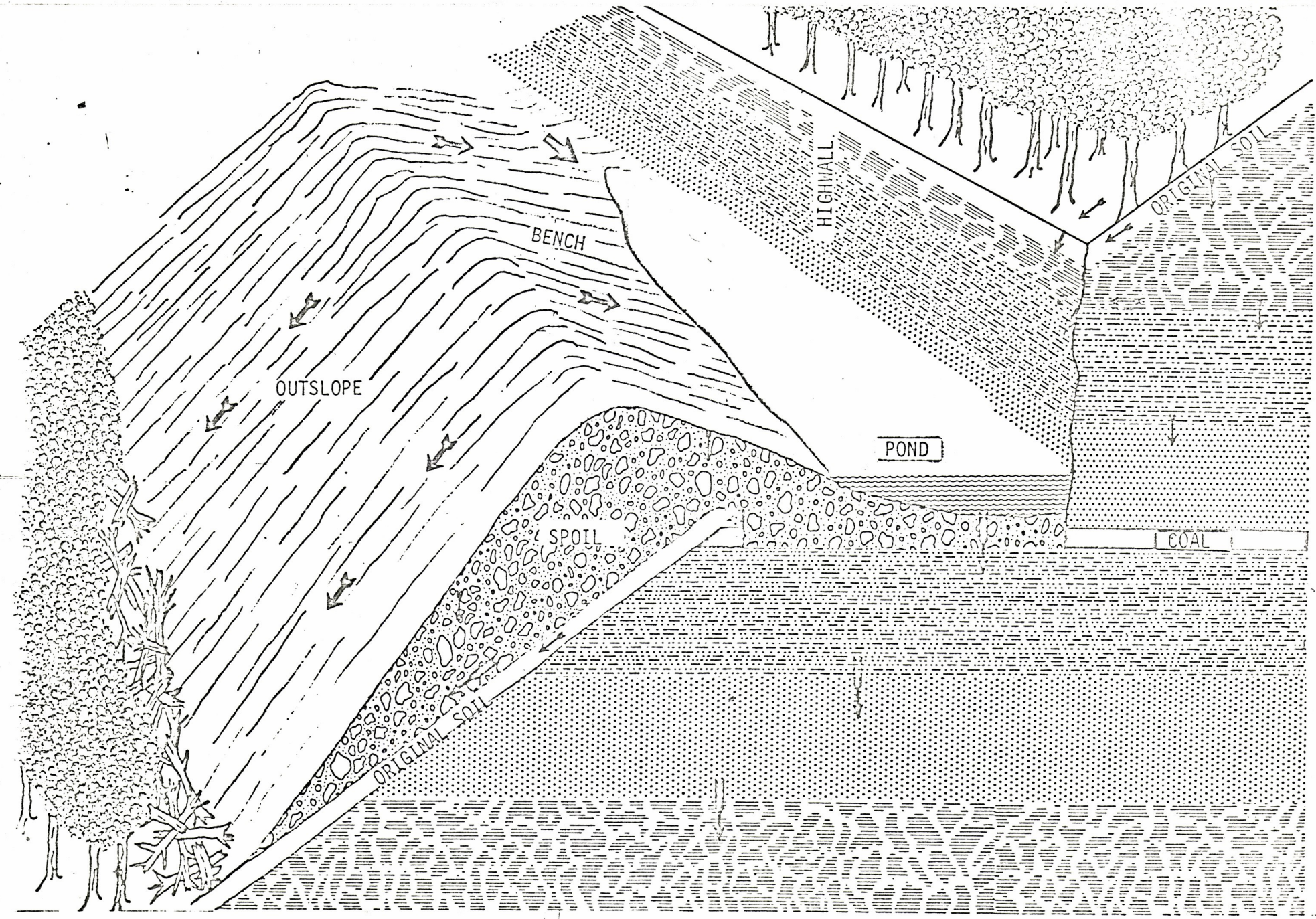

Figure 3.--Typical cross-section and isometric view of contour strip mine showing graded bench, pond, outslope, and windrow of vegetation at toe of spoil. Arrows represent the direction of water movement.

from the auger onto a conveyor that carries it to a truck. Auger mining is a mop-up operation and, as such, it is highly productive.

In addition to the areas disturbed by surface mining, refuse piles formed as a by-product of deep-mine operations are scattered throughout the Appalachian coal fields. As of 1962, there were 27,000 acres of refuse piles in the Anthracite Region alone. They create serious problems because they are inclined to be acid, subject to burning, and are usually located close to population centers. Since these piles are deposited on the surface they are considered as part of the surface mine problem.

In Appalachia about one-fifth of all the coal produced is strip mined. Strip mining is the most efficient way to recover coal. Production per man-day averages 25 tons compared with a little over 11 tons by deep mining. Strip mining recovers 90 to 95 percent of the coal while deep mining gets only 35 to 85 percent. Recovery by auger mining averages somewhat less than deep mining.

Strip mining is also less hazardous than deep mining. Total accidents in strip mines average one per 2.5 million tons mined, just one-twelfth the rate in deep mines.

Prior to 1965, 0.6 percent of the 118 million acres of land in Appalachia had already been disturbed by strip mining for bituminous coal. This amounts to about 740,000 acres. Three-fourths of this or 548,000 acres had been stripped by the contour method and the remaining one-fourth

(192,000 acres) by area stripping. As of 1962, an additional 85,000 acres have been stripped in the anthracite region of Pennsylvania. Mine-access roads have resulted in the disturbance of some 74,000 acres. As of 1970, the total disturbance by strip mining for coal in Appalachia exceeds one million acres. Further land disturbance is being done at an approximate rate of 31,000 acres per year.

Effects on the Environment

Strip mining influences the quality of our air, land, and water; and, through these, plant and animal life and--most important of all--people. The immediate effects of strip mining may be classified as follows: water pollution, air pollution, aesthetics, safety and health hazards, and noise and vibration.

While water is necessary for all life, it is perhaps our most abused resource. Although strip mining is not the major contributor to degradation of our water supplies on a national basis, it is a significant source of pollution in Appalachia. Of the problems caused by strip mining, water pollution is often said to be the most serious. As the protective cover of vegetation is removed and the raw earth is exposed, the stripped area may be subject to runoff and erosion. Silt from eroded areas may choke small streams and turn clear waters muddy. Sedimentation may also contribute to increased flood damages downstream due to reduced channel carrying capacities.

Streams may be further polluted with chemical substances if the overburden is acid. Chemical pollutants affect stream life and water use many miles from mining sites. Whether stripping results in serious acid stream pollution depends on the geology of the region and mining methods. Acid pollution is not limited to strip mining. Coal mining, by whatever method, produces sulphuric acid. It has been estimated that more than three-fourths of stream acidity comes from deep mines and the refuse associated with them. States that have strip-mine legislation have not solved this deep-mine pollution problem. Thus acid pollution is a coal-mining problem, not just a strip-mining problem.

Some erosion is inevitable on all fresh spoil banks, as it is on all bare soil. Erosion is not a serious problem in area stripping where most of the soil movement is between spoil ridges and little soil and rock actually leave the stripped area. Such erosion is detrimental only when it is severe enough to hinder or prevent revegetation. Erosion is much more serious in contour stripping. Strips usually lie on steep mountainsides where water volume and velocity may combine to create an erosive force of considerable magnitude.

Access roads appear to be responsible for just as much erosion as the mines themselves. Whereas the strip-mine floor is relatively flat, coal-haul roads usually involve long grades which accumulate water. Access roads generally follow drainages, and much of the sediment which erodes from roadbeds reaches streams.

(Page 14a follows)

In many locations, slides or slumps occur when excess volumes of soil and rock are placed on steep slopes and affected by adverse drainage conditions. These slides may mar the landscape, block streams, and increase the extent of disturbed area. They are one of the most serious problems of strip mining in mountain country--a problem as yet far from being solved.

The air pollution resulting from strip mining is usually not a major problem even though air pollution is one of our more serious environmental problems. The most serious air pollutant occurs in the form of sulfur dioxide fumes when exposed coal seams or deep-mine refuse piles ignite by spontaneous combustion or other means. Localized pollution also results from dust and other fine matter generated by the mining industry. The problems can and do result in a disagreeable nuisance for residences and businesses in the immediate area especially along coal-haul roads.

One criticism of strip mining is that it creates ugliness. It is generally agreed that 60- or 80-foot high piles of black or gray rubble are aesthetically undesirable. Contour stripping extends for miles in the scenic mountains of Appalachia, denuding hillsides and destroying aesthetic values. Attempts to attract new industry to these areas often fail because industry executives and their families are repelled by the devastated landscapes and general squalor of the environment.

Safety and health hazards of various types frequently result from strip-mining operations. Such operations are characterized by steep slopes and, in many cases, by deep pools of standing water, which constitute an attraction and a hazard for young children. In contour stripping, landslides are a potential danger for those who live in the valleys below. The fact that much of the stripping is done in isolated areas is probably responsible for the low frequency of serious accidents. A more serious problem is created by heavy

equipment used to transport large quantities of coal from the mine to the tipple or railhead, increasing traffic hazards and spreading dust and debris on roads and highways in the area.

Strip mining is inherently noisy; there is no quiet way of moving tons of earth and rock. Mining equipment can typically be heard with annoying clarity at a distance of several hundred yards from the site. Blasting associated with mining operations may cause annoying vibrations for a substantial distance, although the extent of actual harm resulting from blasting is probably nil.

Strip mining has also been criticized as destructive of useful land areas. Trees and other vegetation are removed from the areas before stripping operations begin. A potential timber resource is destroyed in the process, but this is probably an insignificant amount of the vast forest reserves in Appalachia. A small percentage is logged and sold, especially where sawlog size trees are involved. Wildlife cover is destroyed, but this is at least partially offset by the creation of favorable "edge effects" and openings in continuous forest cover. To the extent that strip mining leaves land in an unusable condition, it reduces the total available supply of land for productive uses. But generally speaking, the stripped land plus that which may be stripped is an insignificant part of the total land-use picture. As was mentioned elsewhere approximately one million acres have been disturbed by strip mining. This is less than 0.9 of one percent of the land in Appalachia;

this was generally land of low productivity to begin with. Furthermore, much of this land can be put back into production by reclamation. Thus the impact on land productivity is slight compared to the impact on the environment.

There are other effects of strip mining; however, they are not so readily apparent. When massive rocks are fragmented during surface mining, the resulting piles of material contain considerably more void space than existed before. As a result, certain desirable hydrologic effects may occur. A significant portion of the rainfall may be trapped in ponds and depressions and behind spoil banks where it infiltrates the spoil to augment groundwater supplies, rather than running off rapidly to nearby streams. Because water is detained in spoil banks, drainage should continue for a long time before the water level declines to that of adjacent streams. Thus, streams near strip-mined areas may maintain a longer sustained flow during dry weather than those draining undisturbed ground. These effects have been demonstrated on mined drainages elsewhere but not as yet in Appalachia.

Mine-access roads, when properly repaired and maintained, can be of considerable value since they may be used to promote the multiple-use potential of land over extensive areas. Accessibility for forest fire protection, recreation, and management activities can mean the difference between use and isolation.

Legislation and Controls

Strip mining is everywhere subject to state regulations. Laws vary from state to state, but in general they provide that the operator (1) obtain a permit or license prior to mining, (2) post a bond for faithful performance of statute requirements, (3) make reports on the progress or extent of operations, and (4) reclaim the affected areas.

The penalty for not complying with the regulations is a fine or the forfeiture of the bond. Moneys collected from fees, fines, and forfeited bonds are generally put in a special fund for administering the law, for reclamation work neglected by the operator, and for reclaiming areas that were mined before the law was enacted.

The law may also provide that an operator who has not repaired the surface within a specified time will be given no further stripping permit until he has done so. In some cases the law prohibits the issuance of new permits to an operator who has forfeited a bond.

Efforts are continually being made by conservation groups to strengthen the legislation in almost every state in which strip mining is going on.

In addition to reclamation, the field of water pollution control is one in which state agencies are the primary regulatory authorities. The Federal Water Quality Act of 1965 delegated to the states the power to set and enforce standards of water quality.

Enforcement of laws has been a state responsibility and is administered either through existing state agencies or through a separate division of

reclamation. Mining associations have been formed in some states, and there is some internal policing to insure that all members comply with state laws.

Federal regulation of strip mining has historically been minimal. However, such legislation has been proposed to take care of situations where state laws and regulations do not provide sufficient authority to properly regulate strip mining or to prohibit such mining where reclamation is not feasible.

Reclamation Programs

Reclamation is a term rather loosely used to cover a wide variety of practices to improve the conditions of strip-mined lands after the mineable resource is extracted. Reclamation laws and methods vary from state to state and may cover all surface mining or only coal mining. Generally, two operations are involved: grading and revegetation. Grading requirements range from merely "striking off" ridges to complete back-filling to original contour. Revegetation seems to be a universal requirement, but a recent survey by the Department of Interior showed that only 15 percent of the sampled sites had enough vegetation to provide adequate protection of the site. Pennsylvania is the only state with extensive regulations to insure that water leaving the mined areas meets specific minimum standards.

In most states the mine operator rather than the landowner is held responsible for reclamation. Industry-sponsored reclamation associations

perform some phases of reclamation for member companies. In West Virginia, Soil Conservation Districts contract with mining companies to do reclamation work.

The Forest Service has conducted the only continuous long-term program of reclamation research. Their scientists have been working on revegetation of spoils since the 1930's, and research in the engineering and hydrology fields was initiated in 1962. Other federal agencies have done some research on various phases of strip-mine reclamation from time to time. Studies have also been conducted on an intermittent basis by some universities and state agencies in Appalachia. Mine operators have often participated in these studies on an individual basis or collectively through their associations. As a result of these programs marked progress has been made in the field of revegetation, but many of the difficult engineering and hydrology problems remain unsolved. The reclamation research effort--even if all programs are included--has been quite modest compared to the serious impact that surface mining has on the environment of Appalachia.

Basic Reclamation

Basic reclamation includes the minimum steps that must be taken to protect the environment. The mined areas must be stabilized and revegetated as soon as possible to control chemical or sediment pollution of the streams. All reclamation laws and programs should be designed to meet these minimum requirements.

Basic reclamation should be considered as an integral part of the total mining operation. It should start during the mining operation to insure that toxic spoil is buried, material favorable to plant growth is placed near the surface, and spoil is placed in a stable condition. Some grading is usually necessary for drainage and erosion control, greater stability, preparation for revegetation, and aesthetic purposes. Revegetation is needed to provide a permanent cover for erosion control and aesthetics. Impoundments may be necessary on benches or in drainages leading from mined areas for sediment control. Treatment of acid water may also be necessary on some sites to prevent chemical pollutants from entering streams.

The main purpose of this report is to describe in detail the best known techniques to achieve basic reclamation, and most of the following sections are devoted to this end.

Reclamation for Productive Use

Surface-mined lands also offer an opportunity for development beyond basic reclamation to serve special uses. Mined areas occur in many different situations and the loose spoil can be shaped easily for many purposes. Many areas have been developed for timber production, Christmas trees, and some as hayland. Less frequently development has been for special wildlife areas, reservoirs or recreation lakes, etc.

The factors to be considered in reclaiming land for some of the more common uses are outlined in a later section. When reclamation is considered

as an integral part of the mining process, it becomes more efficient and economical to develop mined areas for special uses. Detailed land use studies and plans should be developed before mining operations begin.

RECLAMATION PRE-PLANNING

Each year in Appalachia, millions of dollars are spent to reclaim mined areas. Proper planning can insure that restoration funds are well spent. The best technology suited to the type of reclamation desired and conditions of the site should be integrated into the overall mining plan. Pre-planning is desirable to achieve adequate basic reclamation, but it is especially important when the areas are to be developed for special uses. Whether mined lands are reclaimed as individual operation permits or as part of long-range land use development, planning reclamation in advance of mining is cheaper and more effective than waiting until operations cease.

Comprehensive Land Use Plans

Most states have land use planning commissions on a state or county level. Since mining can be anticipated to be an important part of the economic development of Appalachia, reclamation of these areas can be incorporated into long-range land use plans. Land development in Appalachia should probably be done on a watershed basis which would require coordination between several political units.

When comprehensive plans for watersheds or counties are contemplated, factors usually considered are development of transportation systems, industrial and residential sites, recreation areas, reservoirs, and other special uses to meet the needs of an expanding economy and population.

Mined areas can be developed to meet many of these needs. Close cooperation between planning commissions, landowners, and strip mine operators would be necessary.

In many cases the operator would have to be subsidized for development beyond reclamation required by state laws. However, with advance planning special use areas could be constructed as part of the reclamation process at a fraction of the cost of developing such areas from scratch. For instance, mine operators could be subsidized to construct recreation lakes on mined areas or design major coal-haul roads to meet county standards as part of mining and reclamation operations cheaper than the county could construct these facilities by contracting to construction companies.

Recently zoning has also become part of the mining and reclamation picture. There have been attempts to prevent mining in some areas designated as residential, recreation, or wilderness. Some states require more intensive reclamation near highways, towns, and in headwaters of streams having high value for recreation or municipal water supply.

Individual Mining Plans

Whether or not an area is to be reclaimed as part of an overall land use plan, reclamation should be planned in advance for each area to be mined. Many states require a reclamation plan before an operating permit is approved. However, by pre-planning each phase of a mining operation,

better road location is possible; and mining and reclamation can be conducted more economically.

If areas near the proposed mining site have already been mined, information about coal and associated overburden, spoil materials, soil mantle, and drainage can easily be obtained. In unmined areas core drilling may be necessary to determine this information. Field observations and measurements of each site help determine drainages, seeps, and steepness of slope so that area to be disturbed and amount of overburden to be removed can be calculated and problems causing instability can be avoided. By planning revegetation in advance, adequate amounts of seed, planting stock, and fertilizers can be computed and ordered so that they are available when needed.

COAL-HAUL AND MINE-ACCESS ROADS

Roads constructed by surface-mine operators in the Appalachian coal field constitute approximately 10 percent of the total area directly disturbed by surface mine activity. These roads provide access to mine sites for workers and equipment and some of them are the first leg of the route over which coal is hauled from mine sites to points of use.

Categorically, these roads begin at some public road and end at a surface-mine site. They are heavily used, and their construction is subject to stringent economic restraints. When their use life as coal-haul routes is complete, they are abandoned by the mine operators. Upon abandonment most coal-haul roads receive some treatment aimed at minimizing their further effect upon adjacent resources.

Studies have shown that typical mine roads in eastern Kentucky exhibit poor alignment, excessive grades, insufficient strength and durability, and poor drainage. Mine roads in other Appalachian states appear much the same as those in Kentucky. During its use life the typical coal-haul road requires almost constant heavy maintenance, and when it is abandoned the typical haulage way continues to exert high levels of deleterious influence upon adjacent resources.

There are now an estimated 10,000 miles of coal-haul roads in Appalachia; approximately one-tenth is currently in use or recently abandoned. An

estimated additional 500 miles of haulage roads are constructed each year. Non-application of rational design standards, construction without standards, poor maintenance, and irrational abandonment procedures allow these roads to contribute up to 2,880 cubic yards of sediment per mile of road per year to Appalachian streams. In dry weather these roads are very dusty, and in wet weather they are muddy. Knowledge is currently available for much improved construction and maintenance; the problem is to apply this knowledge.

Design criteria applicable to heavy-duty, off-highway haul roads; and design standards describing acceptable roadway location, grades, widths, strength, durability, and drainage have been developed by the U. S. Forest Service through years of engineering study substantiated by volumes of field data. These criteria and standards are applicable to Appalachian coal-haul roads. Applicable criteria and standards have also been developed by large timber and mine operators and by various states and other governmental agencies, but these companies and agencies have not collected their standards and made them available in concise form to the public.

The following discussion describes in a general manner some design criteria applicable to haul roads. Throughout the discussion, concepts and techniques adhered to by the U. S. Forest Service are used, not because they are necessarily better or more applicable than others, but because they are satisfactory and are available to the public.

Haul Road Design Criteria and Standards

Factors affecting design criteria for roads include:

(1) The expected traffic volume per unit of time which will be generated by all probable users.

(2) The weight per axle or tire which those users will exert upon the travelway.

(3) The time duration through which each user can be expected to use the road.

(4) The speed at which traffic should flow during periods of maximum traffic volume.

(5) The expected ratio of available engine power to gross vehicle weight for the haulage vehicle which will be the primary road user.

(6) The bunk width of the haulage vehicle which will be the primary road user.

(7) The ability of the forest floor below the road to act as a sediment filter or trap.

If plans are to use the road to serve traffic from secondary sources, then the characteristics of that secondary traffic should also be weighed when design standards are selected. If the design standards demanded by probable secondary uses are incompatible with the standards demanded by the primary use, the feasibility of staged construction or construction cost splitting should be investigated.

Some specific design standards which depend upon the above design criteria pertain to acceptable limits for:

(1) Variation in horizontal and vertical alignment,

(2) Adverse and favorable grades,

(3) Road cross section shapes and dimensions,

(4) Width of forest floor filter zone between the road and stream below the road.

(5) Travelway strength,

(6) Surface durability,

(7) Strength of structures which facilitate cross drainage, both for natural water courses and for roadway ditch relief,

(8) Flow capacity of drainage structures to facilitate cross drainage of natural water courses.

Haul Road Route Location

Based upon design standards, number (1) through (4), several possible roadway routes should be located. Aerial photographs and topographic maps are useful for location purposes. The routes should be delineated upon maps for study. After thorough study, all routes except those which exhibit the most desirable attributes should be eliminated.

Those routes still under consideration should be "walked out" on the ground. While "walking out" these routes, notes describing possible construction difficulties and both natural and cultural hazards should be carefully prepared. Then appropriate adjustments should be made on the maps.

At this point, the most desirable route should be selected for further study and design efforts. The selected route location should be flagged in the field; it should reflect an awareness of the specific standards which will apply to the finished haul road. When the planning job is properly done, the mine road can be constructed along the flagged route to the desired design standard without undue, unanticipated, or wasteful efforts during construction.

Drainage Control

Drainage control structures are one of the more important items on any roadway. Their design depends upon both the length of time which the road will be used and the hydrologic data for the area. Hydrologic data which should be considered include the magnitude and intensity of the design storm and the shape and steepness of the drainage area above the structure.

In the Appalachian coal field problems due to the presence of acid water are chronic and severe. Drainage control facilities constructed of materials which deteriorate in acid water are unsuitable where acid is present or can be anticipated.

Drainage control structures on any coal-haul road should be sized after weighing the cost and probability of failure. All states in the region have sizing charts and techniques used by their highway departments for culvert and drainage structure design. These charts and techniques are easily adapted for use, but generally have been little used on mine roads.

Roadway Cross Section Shape and Dimensions

Roadway cross sections primarily express the shape and width of the travelway, and the width and shape of the shoulders. Factors affecting selection of travelway cross sections are listed in items (1), (4), and (6) in the factors which bear upon haul road design criteria.

Roadway cross sections are either single lane or double lane. These reflect the expected traffic volume. Subclassifications based upon the type and size of vehicle which the road must serve, when used with the volume category, usually permit a fairly precise description of the cross section. In borderline cases, secondary and future needs may dictate the proper cross section.

Handbooks and manuals used by the U. S. Forest Service in design of timber haul and area access roads present examples of limits and factors which may be useful in selecting adequate road cross section classes for coal-haul roads.

Width is probably the most important attribute of the roadway cross section so far as traffic volume is concerned. Traffic safety, road maintenance costs, and road surface drainage also must be considered when cross section shapes are designed and constructed.

Cross sections are required which facilitate quick removal of water from the travelway without causing erosion. Cross sections which allow traffic to flow smoothly around curves without undue stress upon vehicles, drivers, or travelway surfaces are necessary.

If a crown shape or an "inward" transverse slope is used, shallow "V"-type roadside ditches must be provided and cross drains must remain functional. If an "outward" transverse slope is used, ditches and cross drains for concentrated flows are not necessary. However, fill outslopes must be constructed to resist erosion.

Cross section design standards and criteria applicable to mine roads are contained in U. S. Forest Service road design manuals and in "A Policy on Geometric Design of Rural Highways" published by the American Association of State Highway Officials. Information is also available from other sources, but, as yet, Appalachian coal mine operators have made little use of it.

Travelway Strength and Durability

The strength and durability of a road are dependent upon the characteristics of the materials used in construction of its travelway. Roads for low traffic speed, volume and weight, may require only the "native" material construction of the basic roadway cross section. This material is known as the subbase.

Roads constructed to serve slightly higher traffic requirements may need an additional layer of ballast material or a layer of the subbase material may have to be artifically strengthened. This layer is known as the base-course and its components must be of higher quality than the native material

of the subbase. If the base course will serve as the travelway surface it must be stable, resist abrasion, resist penetration by water, and have capillary properties which enable it to replace moisture lost through surface evaporation.

Roads for high traffic requirements need a surface or wearing course in addition to the subbase and base course. If this third layer is applied, then the requirements of the base course are somewhat altered.

Haul-road travelways which are under-designed or constructed so that they undergo excessive plastic deformations when subjected to their expected traffic loads result in excessive maintenance and "down-time" costs.

Extensive research has been accomplished and reported on materials and design standards for road base courses and surfaces. A chart, consolidating information from many sources and typical of reports in this field, is given in the 4th Edition of the Civil Engineering Handbook, edited by Leonard Church Urquhart and published by McGraw-Hill. Field observations indicate that this body of knowledge is little used in the coal fields.

Maintenance

There are four attributes of good maintenance on any heavy duty haul road. These are: technical skill, knowledge of the materials used, knowledge of the physical laws which enable control of these materials, and foresight. All four must be available and applied if a road is to be kept serviceable

and exert a minimal undesirable impact upon other resources. The simultaneous presence of these four attributes is rarely observed on Appalachian mine roads.

No serious attempt has yet been made to separate the effects of poor design and construction from the effects of improper maintenance. Field observations indicate that resistance to adequate construction financing for mine roads is typical and leads to excessive maintenance activity for the duration of road use, to excessive vehicle repairs, and to unduly high environmental impact.

Maintenance failures fall basically into two categories. First, maintenance is accomplished for the sole purpose of maintaining the flow of haulage traffic. The impact upon the surrounding environment seemingly receives little thought. Second, there is little concept of preventive maintenance and maintenance work is accomplished only after a definite need is apparent.

Typically, maintenance is applied only to the travelway surface. Drainage facilities receive little attention until their failure damages the travelway itself. Functional failure of roadside ditches due to sloughing road cuts, flow line grade inconsistencies, and improper disposal of road surface materials during travelway maintenance are common. All of these increase the need for subsequent maintenance; and impose harm upon the environment.

Abandonment or Disposition of Mine Roads After Completion of the Mining Operation

After its primary use is served, the typical coal haul road is abandoned by its builder. It may be completely or partially abandoned, or it may continue to be used. Correct procedures will greatly reduce both the magnitude and time duration of pollution from abandoned mine roads.

For complete abandonment, the roadway should be returned to a near natural state and further traffic should be completely barred. Proper procedures for partial abandonment will range from those appropriate to complete abandonment to those proper for continued use.

If traffic volume will continue to be significant--and mostly by others than the original mine operators--responsibility should be transferred to the appropriate governmental body or private user. In this case, abandonment treatment per se is not required.

For complete abandonment, the mine operator should treat the road to prevent any further environmental disturbance. The travelway surface should be scarified and it and the road fill slopes should be mulched and planted to grasses, shrubs and trees. Side ditches should be obliterated and grade dips or water bars constructed to handle roadway cross drainage. Culverts and other structures for natural water courses should be removed and a channel constructed to handle at least 1.25 times the flow capacity of the original channel. Finally, vehicle access to the roadway should be completely and permanently blocked.

Though minimizing environmental impact is the only criteria for judging the effectiveness of complete abandonment, partial abandonment must jointly allow efficient passage of vehicles and maintain the impact upon the environment at whatever minimum level is commensurate with the roadway use.

Usually partial abandonment requires that the roadway cross drainage and natural cross drainage facilities be revamped. The use of grade dips and water bars should be maximized and fords constructed to replace structures at stream crossings. Roadway vegetation should be limited to grasses and legumes or small shrubs. Road fill slopes may be planted to trees.

In the partial abandonment case, the need for some regular inspection and maintenance is inherent. The responsibility here rests logically with those for whom the road is held open rather than with the mine operator.

Observations made on abandoned Appalachian coal-haul roads indicate that little consideration has been given to determining the proper level of abandonment.

A New Approach Needed

As has been stated, knowledge is available for much improved mining roads. The problems are to find ways to (1) include as part of road costs all damage to the environment and to parties other than the coal operator, and (2) show operators that under-financed construction results in operation costs which can more than offset savings during construction.

Though some states now include road standards in their surface-mine regulations, mine roads have not received attention commensurate with the damage they inflict. All involved parties need to take a new look at the situation. At the same time, those working with coal operators should attempt to convince them that better mine road construction and maintenance will increase mine operation efficiency.

In a broader context, the full benefit of mine roads will not be realized until they are deliberately fitted into local and regional land and resource use plans. As yet, no Appalachian state has plans detailed enough to significantly aid in the selection of mine road design criteria, route locations, construction standards, or abandonment procedures.

Within this same context, until land and resource plans are available for consultation, any mine road which is built and/or abandoned runs great risks of contributing undue and unnecessary effects upon the environment.

MINING AND SPOIL HANDLING

Surface mine activities typical of contour strip mines in mountainous Appalachia consist of four distinct operational stages. In stage one, the lithologic strata--the overburden material covering the coal--are removed. In stage two, the debris composed of fragments of this overburden material is cleared away to allow efficient operation of equipment used to lift coal and load it onto trucks. Stage three consists of lifting and loading the coal onto trucks. Stage four involves grading and shaping masses of the fractured material. The methods, techniques, and skills used in these four processes strongly influence the success of any subsequent site reclamation measures and are largely responsible for the environmental impact of the mining process.

Here, the first three stages are described in the sections covering excavation and overburden handling; the fourth stage is discussed in the section covering reclamation grading and spoil handling.

Environmental impact during mining processes is greater per unit of time than it is during and after reclamation grading. But unless the finished product of the spoil grading is a site which resists erosion, one that can be quickly vegetated, and one that does not foster undue on-site or off-site chemical pollution, the total impact of the graded site over time is greater than that during the active mining.

Mining Processes: Current Methods of Excavation and Overburden Handling

Several distinct surface-mining techniques or methods are currently used in the Appalachian coal region, each has its coal recovery characteristics, and each creates its own reclamation problems. These mining processes per se have recovery of coal as their sole objective.

Single Seam; Single Cut

This is the most common site condition and the simplest excavation technique on contour type strip mines in Appalachia. One mineable coal seam is present and one cut is used to uncover the coal. Historically, the dimensions of the excavation cut have been controlled strictly by the capability of available equipment and site geology. Recently some states have imposed legal restrictions on excavation dimensions based upon scientific studies. The restrictions also limit the volume of coal which can be recovered.

Single Seam; Multi-Cut

One mineable coal seam is present and two or more parallel cuts are taken in sequence to uncover the coal. This method has an inherent flexibility for handling and placing overburden materials. Historically, it has been used where high overburden volumes in conjunction with wide excavation benches created overburden disposal problems which affected mining efficiency. Recent legal limits set for single cut excavations have caused an increase in multi-cut operations due to its overburden handling flexibility. If the

same equipment is used, it allows greater coal recovery from a site than does the single-cut technique.

Multi-Seam; Single Cut

Two or more coal seams are taken by a single excavation cut. The elevation difference between the two seams must be small enough for available equipment to take both. Within legal constraints, excavation economics control the size of the cut. Because two or more seams are taken, economic factors are less restrictive and more coal is recovered than in single-seam operations. Coal is first recovered from the seam of highest elevation, then successively from each seam until the lowest seam is taken.

Multi-Seam; Multi-Cut

Two or more mineable seams are present in close elevation proximity, and two or more parallel cuts are taken in sequence to uncover the coal. In a given cut, the order of coal recovery is successive from the top seam to the bottom seam, however, legal and economic restraints often dictate interplay in the recovery order between cuts and within seams. Modern, more capable excavation equipment is increasing the use of this technique. At a given site with given equipment the maximum volume of coal is recovered.

Auger Mining

When auger techniques are the sole method of coal recovery only enough overburden is excavated to provide a bench 35 feet to 40 feet wide for use of the auger equipment. The auger technique is often used as an adjunct to

other techniques on single-seam and multi-seam sites. In such cases, the auger is used only from the innermost cut, and in multi-seam situations it is used from the topmost seam to the bottommost seam in successive order.

Coal recovery on reserves mined by auger techniques average less than 50 percent. The 50 percent not recovered oxidizes and is worthless for later mine operations. However, auger techniques are well suited for thin or parted seams or where little coal remains between the innermost strip cut and old deep-mine workings.

Mountaintop Stripping

In this situation an area type strip-mine operation is conducted on a site which generally is considered suitable to strip mine by contour methods. The coal seam or seams outcrop a small elevation distance below a mountaintop or a broad ridge top. Multi-cut excavations disturb the entire mountain above the lowest seam mined. Where available excavation equipment is capable of handling the overburden, and where legal restrictions are not prohibitive, 95 percent of all coal in all seams on the site can be recovered.

The first cut is a rim cut at the outcrop of the lowest seam to be taken. This cropline cut may not be made on all faces of the mountain if disturbance on some slopes is legally restricted. In that case, subsequent parallel cuts move the highwall from the rim cut face through the center of the mountain toward the restricted faces. The rim cut circles the mountain

and subsequent cuts move the highwall face closer and closer to the center of the mountain until no highwall remains.

Reclamation Spoil Handling and Site Grading

Mined Site Conditions

Each mining technique produces its own reclamation problems. These problems vary in intensity between sites and among operations according to overburden and terrain characteristics and according to the size and shape of the disturbed area. Single-cut and multi-cut operations present highwall faces, excavation benches or pits, fill benches, outslopes and usually some spoil heaps or ridges stockpiled upon the outer edge of the excavation bench and/or the inner edge of the fill bench. Multi-cut site dimensions and spoil volumes tend to be greater than those of single-cut operations.

Augered sites have small highwall heights and narrow excavation benches. Fill benches are present, but narrow; and a small volume of stockpiled spoil usually is heaped upon it. Outslopes are short. The exposed face of the coal resembles a narrow honeycomb and may exhibit seepage problems similar to deep-mine openings.

Mountaintop sites present problems which are a combination of those found on multi-cut operations and those typical of sites stripped by area-type surface mining. All faces which have been rim cut have outslopes, fill benches, and spoil heaps or ridges piled upon the inner portion of the fill

bench. No highwall exists. Over most of the disturbed area spoil is distributed in a manner which resembles a series of ridges and valleys. Where the last cut was taken, a coal pit exists. The spoil generated when a mountaintop is surface mined presents problems simply because of its great volume.

On all sites, erosion and siltation problems attending runoff of precipitation are present. Noxious and infertile materials in the spoil heaps may be present and often cause acid water and vegetation establishment problems.

Goals of Reclamation Grading

There are three purposes for spoil handling and site grading in mine site reclamation processes. They are (1) to reduce the effect of mine-generated pollution upon both the site and upon off-site resources, (2) to produce a landform which is desirable and easily used, and (3) to restore, insofar as possible, aesthetic value to the site. Reduction of pollution requires that: (1) noxious spoils be buried or otherwise placed where pollutant production is minimized and where the pollutants that are produced can be controlled by secondary methods, (2) site surface drainage patterns be developed which minimize erosion, and temporary erosion barriers be constructed to serve until vegetation can do the job, and (3) outslope spoil depths be limited so that internal stresses within that spoil mass do not exceed those of incipient sliding.

Developing a desirable landform requires that the gradients and dimensions of the reclaimed site be compatible with the future uses planned for the site. If no specific future use is recognized, the site should be shaped to meet specifications of the most restrictive probable use.

Restoration of pre-mining aesthetic value to a mined site is, for most sites, an impossible task and can be practically approached only on sites having level or rolling terrain. On other sites, a measure of aesthetic value will be restored if the requirements of the first two reclamation purposes are met.

Grading and Spoil Handling Methods

Historically and currently the contour strip mines of Appalachia form a bench and an outslope. There are two bench variations and two variations of side-cast outslopes. Either bench variation may be used with either of the two outslope variations.

Bench; Outward Slope

This technique creates a sloping surface which covers the excavated bench and portions of the fill bench. The slope is away from the highwall. The surface is composed of materials which were temporarily stockpiled within reach of available secondary spoil handling equipment during the mining process. Surface gradients may range from very gentle, nearly flat, to the relatively steep slopes found on sites rebuilt to their original contour. The typical bench slopes lie somewhere between four and ten degrees. In current practice

these benches are not provided with water bars to control sheet runoff, and rilling and erosion are common.

Generally any temporary spoil stockpiles are located so that their center of volume is near the outer edge of the excavation bench. To obtain an outward sloping bench requires that this center of volume be moved some distance toward the highwall face. The greater this distance, the more grading work is required.

This bench shape places the greatest volume of spoil where it is least likely to contribute stresses which cause spoil slides. Surface drainage is positive, and erosion can be held within tolerable limits if runoff control measures are installed.

Bench; Back Slope

In current practice strip-mine benches are most often sloped toward the highwall, or in a word, backsloped. Slope angles on backsloped benches may range upward from zero, but the typical backslope is between 4 and 12 percent and averages about 7-1/2 percent.

When this method is used, positive surface drainage is developed which reduces rilling and erosion at random locations on spoil outslopes. Runoff is directed toward the highwall where it can be channelled on a gentle gradient toward a natural drainage or toward some flume or conduit where it can be led off the disturbed area. Channels on the bench should be wide, have gradually sloped sides, and be centered at least 30 feet away from the

highwall face. Otherwise, sloughing of the highwall face may block them entirely and create pools or ponds. These unplanned pools are suspected of contributing to spoil slides through seepage of pooled water along the surface of the excavated bench and down the interface between the natural terrain slope and the outsloped spoils.

Backslope benches have the maximum spoil depth at their outer edge. Unless care is taken during their construction, excess spoil depth at this outer edge creates internal stresses which exceed those which the spoil or underlying native material is capable of resisting, and a spoil slide occurs.

The backsloped bench allows the minimum possible distance between the center of volume of the temporary spoil stockpile and the center of volume of the spoil on the shaped bench. Grading requires a minimum of effort and expense.

Outslope; Natural Repose

Lithologic debris, such as strip-mine spoils, will form slopes when cast freely into a heap or pile. Where mitigating influences are absent the angle of these slopes is known as the angle of repose. This angle varies somewhat with spoils of various lithologic composition, but its range is rather narrow. Usually these spoils will lie at angles between 33 and 38 degrees when allowed to fall as they will.

Construction of an outslope which lies at its angle of natural repose is simple. Spoil is pushed beyond the edge of the excavated bench and allowed

to fall or roll as it may. Historically, little attention has been given to the volume of material disposed of in this manner. As spoil volumes increased with the capability of excavation equipment, spoil depths in the outslope became greater, and excessive internal stresses became common. Unstable spoil outslopes became a major problem. Natural-repose outslopes are suitable where spoil volumes are small or where most of the spoil can be placed upon the solid excavation bench.

The advantages of allowing outslope spoils to reach their angles of repose are that it is a simple and economical technique and that it results in a minimum area of sloping surface exposed to erosive runoff. Also, the total area of the mining disturbance tends to be minimized.

Outslope; Reduced

In recent years the capability of excavation equipment has expanded. With that expansion the volume of spoil generated at a given site has grown. Disposition of these greater spoil volumes upon outslopes at the natural repose angle caused slides. Temporary stockpiles upon the excavation bench did not allow an adequate maneuvering area for mining equipment. To solve these problems the state of Kentucky developed the reduced outslope technique. This technique reduces the slope angle of the uppermost portions of the outslope face and avoids the situation of spoil-bound mining equipment. If properly done, it avoids excessive spoil depths on the outslope.

Outslope face angle is reduced by pushing some spoil material down the outslope face. Usually a bulldozer is used. Beginning at the outer edge of the excavation bench, where only a slight spoil depth is allowed, the dozer moves spoil down the outslope. The spoil is allowed to dribble underneath the dozer blade and form a slope which is less steep than either the repose angle or the natural slope of the site terrain. The downhill face of this spoil does fall at its repose angle. When the spoil depth accumulated at the intercept of this natural repose slope and the reduced slope approaches the critical depth for the particular spoil, push-down operations cease.

The slope reduction technique has the advantage of allowing more spoil to be safely disposed of than any technique except the valley fill, and it is much more suited for widespread use than is the valley fill.

A disadvantage is that long, unbroken slopes are formed which are subject to severe erosion. Another disadvantage is that the total area disturbed by the mining process is greatly increased.

Plugging Auger Holes

Wherever augering techniques have been used the auger hole openings should be plugged. The object is to prevent or inhibit oxidation of the coal which has not been recovered and thus minimize acid seepage problems. Spoil may be used to plug the holes. To insure that the plugs remain in place, highwalls should be stepped. The step benches should be of a width equal to twice the diameter of the auger hole and covered by a spoil backfill.

On sites where only augering has been used the bench may be treated by typical bench and outslope grading techniques. If the site has multi-cut characteristics, the auger holes in each seam should be plugged. This must be done after each seam is augered.

Original Contour; Back Filled

A mining site located in gentle terrain can be returned to its approximate pre-mine configuration. Currently, this technique is used mostly in Pennsylvania where, under certain circumstances, it is required by law. Overburden materials, temporarily stockpiled during excavation procedures, are pushed by secondary spoil-handling equipment back into the pit developed by overburden excavation and coal lifting. Enough material must be stockpiled during the mining process to allow grading operations to completely fill the pit. A large volume of material is required and reclamation grading is extensive.

Grading to the original contour develops long slopes. Rilling and erosion upon these long slopes is always a danger and, unless they are protected by water barriers, erosion is often devastating.

Unless a specific future use demands reconstructing the site to its original contour, funds may be spent more advantageously building water barriers and promoting vegetative cover. Long, unbroken slopes are not desirable under any circumstances.

Highwall Reduction

The name is derived from the fact that the angle of the highwall face is reduced. This site shaping technique may be used on any mine site which leaves a highwall, but is most applicable to auger-only sites to help seal the auger holes. Highwall reduction is required by law in some states and it is sometimes used to improve appearances in areas of high aesthetic values. It also allows general access to otherwide semi-isolated areas above the mined site, and reduces the likelihood of personal injury in falls from the highwall crest.

Typically, the highwall is fragmented by blasting as the first step in highwall reduction. A considerable volume of fragmented overburden falls directly onto the bench. The remaining loosened debris is pushed onto the strip bench until the face between the bench and the undisturbed area above the treated highwall lies at an angle of approximately 45 degrees.

Highwall reduction causes disturbance of additional area (that above the original highwall). In steep terrain, this additional disturbed area may be large. Some of the relatively flat areas on strip benches are covered by rocky debris when highwall reduction is used; this may severely limit the range of future site use. In any case, it is an added economic burden, the necessity and advisability of which should be weighed based upon individual site requirements.

Mountaintop; Rolling Grade

By definition this applies to reclamation grading on sites where mining operations have excavated an entire mountain or ridge top. Any rim-cut disturbance on these sites should be treated by bench and outslope methods.

In the majority of cases, spoil handling during mining operations is necessary in order to maintain adequate maneuvering room for equipment. When possible, secondary spoil movement during this phase of operations should be compatible with the desirable finished shape.

Reclamation grading on mountaintop sites should result in semi-rolling terrain with a well defined drainage pattern. Runoff water must be removed from the site by controlled surface drainage. Channels built for this purpose should have low gradients and lead through a series of sediment basins into a natural drainway or into a flume or conduit. Flow force dispersal devices should always be installed at the outlets of these structures.

If sufficient drainage area is available, permanent ponds can be constructed. These should be fitted with grassed, or otherwise protected, emergency spillways.

A mountaintop site offers a wide range of future use. Less off-site impact occurs per unit area of the disturbed site than with contour stripping.

Valley-Fill

This technique allows safe disposal of large volumes of spoil material which may otherwise inflict prohibitive restraints upon mining equipment

maneuverability and exert undue impact upon off-site resources if the normal bench and outslope technique is used. With this technique, the upper reaches of a natural valley are filled with mine spoil.

Valley-fills may be used at sites on terrain with narrow, steep-sided valleys, and where the operation will generate sufficient overburden to completely fill the treated valley. As yet, it has not received wide application. Few valley fills have been designed and fewer still have been constructed according to design.

Careful planning and construction are necessary if stability problems inherent in carelessly constructed massive fills are to be avoided. Maximum stresses at all points within the valley-fill must be kept below those of incipient movement. It is necessary to determine spoil stability characteristics prior to constructing the fill.

Proper internal and surface drainage must be constantly maintained. Internal drainage of the valley-fill mass may be accomplished by constructing French drains in the natural drainway at the valley bottom, and on the sides of the valley which will be touched by the body of the fill. It may be difficult to construct the French drains on the valley sides in one step. If difficulties do arise, these drains may be constructed in steps reaching ever increasing elevations as the fill body is constructed.

Once proper internal drainage is provided, the fill body may be placed. Terrain and equipment capability demand that the spoil material be dumped

into the valley from points along the coal outcrop line. Bulldozers and highlifts can be used to move the dumped material down the valley to the point previously designed for the toe of the terrace of lowest elevation. Spoil movement and placement continues until this base terrace reaches its design height.

Other terraces may then be constructed upon the base terrace in the same manner. When a valley fill is complete, it resembles a set of stair steps with slightly curved treads which are slightly crowned along the line of the original valley bottom. The riser height of each step terrace must be allowed to vary according to slope stability data describing its material.

Proper surface drainage can be secured if;

(1) The elevation of the valley fill crest is higher than the excavation benches adjoining it.

(2) The entire surface of the fill provides drainage toward solid benches or undisturbed terrain. This applies both to the fill crest and to terraces which stair-step down the face of the fill.

If the mining operation has produced a contour bench, the water collected from above the contoured disturbance by the natural drainway and that water draining from the valley fill terrace can be collectively drained along the bench. This water may be released either into another natural drainway or through prepared flumes or conduits. If the mining operation has been of the

mountaintop type, waters draining from the uppermost valley-fill terrace can be channelled into sediment ponds or permanent pools.

Coordinating Operations

In the foregoing discussion, mining processes and reclamation grading techniques have been discussed as separate operations. If the environmental impact of surface mining is to be minimized for least overall cost, these two must be considered as parts of a single operation; each part compatible with the other, and both coherent with the overall goals of the operation.

EROSION CONTROL AND WATER QUALITY

During strip mining natural surface drainage-ways are often obstructed, and water normally moving as subsurface flow is intercepted and brought to the surface at the highwall. Increased erosion and stream sedimentation are serious problems created by strip mining. The control of water flowing within and from surface-mined areas is perhaps the most widely overlooked element in strip-mine reclamation. However, drainage control is without doubt essential in protecting downstream water values.

Sediment yield from a strip-mined watershed is the combined result of erosion from the disturbed area and the transportation of the eroded material from the watershed. Therefore, sediment yield varies, not only with the extent of disturbance within the watershed, but also with the proximity of the disturbed area to the natural stream channels. Thus, surface mines where the outer fill slope approaches the stream channel will yield greater quantities of sediment than those separated from the channel by a forested zone.

The susceptibility of newly strip-mined land to erosion depends chiefly on topography and the physical characteristics of the spoil. As the length and steepness of slopes increase, the amount of erosion increases. Erosion from raindrop splash is generally inversely related to stone content of the spoil-bank surface. The formation of flat-bottomed, steep-sided gullies, so common on banks consisting mainly of soft shale, is due primarily to the ease with which soil particles and aggregates are washed down the slope.

By utilizing preventive measures, such as good water control, mining techniques, and reclamation practices, pollution from surface mines can be held to a minimum. This necessitates pre-planning on the part of both the strip-mine operators and land use managers.

Prior to Mining

Silt Basins

Since stream siltation is one of the most important off-site influences of surface mining, it is essential that necessary steps be taken for the control of sedimentation. Silt basins offer some control of stream siltation by catching and holding much of the eroded material before it reaches the main streams. Silt basins should be constructed in the valleys below areas to be mined prior to any disturbance on the mine site.

Location of silt basins must be given due consideration. Configuration of the valley will play an important part in selecting the dam site. If a projecting tongue of land can be used for one end of the dam, it may materially reduce the fill volume relative to the ponding space above. Likewise, the junction of two drainages offers more storage per unit of dam height than a straight section of stream channel. In any case, selection of dam sites should be made at points where the maximum storage can be obtained with a dam of given height and minimum length.

Perhaps because their installation seems too simple a matter, earth dams may be frequently washed out due to faulty construction and are then

difficult to replace. The difficulty in replacement stems from the fact that there is generally a scarcity of construction material in the first place.

Practically all failures of the dams may be traced to one of two causes; (a) a volume of water so much larger than anticipated that the dam was swept away, or (b) failure to provide an adequate emergency spillway for such water as must flow past the dam.

An important feature of any dam is the apron below the spillway. Unless the channel below the dam is on solid rock or on boulders so large as to be immovable by any expected flow, an apron must be installed. Obviously, if this does not prevent the falling water from gouging the channel the dam will soon become unstable. The apron must protect the full width of the spillway.

A design for silt retention structures within the economic reach of all operators is urgently needed and could be used in hundreds of cases if it were properly developed.

Since most of the settleable solids drop out of suspension quickly in still water, it is unnecessary that the basins remain filled with water. Dams used for silt catchment can be useful for flood-control purposes, too, if they are designed to impound sudden runoff and to begin releasing it immediately so that the storage space will again be available. In this case the dams must be provided with two types of outlets--"storm outlets" and "slow drainage outlets".

The slow drainage outlets are merely small openings in the riser of the spillway. These outlets should be of the proper size to remove the full capacity of the pond in, say, a period of 48 hours.

Scalping

One of the first steps in the strip-mining operation in mountainous country is the removal of existing trees and brush in a process called scalping. Unless the vegetation is to be salvaged, it should be bulldozed and windrowed along the contour at a point where the toe of the spoil is expected to be. Here the vegetation will be in a position to trap soil particles that are washed downward from spoil banks and outslopes.

If trees are merely pushed over during mining activities and are subsequently buried in the spoil, they may act as flow planes for subsurface water, and in this way act to reduce stability of the spoil bank. On the other hand, if all vegetation and litter are removed, there results a spoil-to-mineral soil contact which may act to reduce subsurface flow planes and result in greater stability of the spoil banks.

A mineral soil-to-spoil contact provides much stronger shear resistance than a spoil-to-vegetative material contact. Scalping also eliminates the French drain effect of a buried brush pile.

During Mining

A significant amount of off-site damage from strip mining occurs during the actual mining operation. Some of the highest suspended sediment

loads ever observed from strip-mined watersheds came during mining. Some high streamflow peaks have also resulted from direct drainage of the strip-mine pits.

Often rainfall, runoff, and seepage water collects in the pit area on active mines. Before work can continue, this water must be removed. Hence, the term pit drainage. Pit drainage is used here to mean the removal or discharge of water from the pit area during the actual mining operation.

When water accumulates in an area in which equipment is moving to and fro, much sediment is churned up and put into suspension. A much too common practice is to bulldoze a cut through the bench crest and discharge the accumulated water onto the outslope. Observations indicate that serious erosion occurs on spoil outslopes when water concentrated on the bench is caused to or permitted to flow onto and over the outslope.

Rather than release vast quantities of muddy water over outslopes, pits should be drained so that no additional soil material will go into suspension. This can be done by releasing pit water more slowly through the use of siphons or pumps with outlets below the toe of the spoil. Preferably these discharges should be made into natural drainage-ways where stream channels are gentle.

Pumping or siphoning can be regulated in order to minimize its effect on receiving streams. A relatively constant flow of pumped water can be assimilated by a stream more successfully than periodic slugs or discharges. Water can be pumped into holding ponds which provide for a constant outflow. The holding pond may also act as a settling basin for sediment.

In some cases surface water from above a strip mine can be diverted away from the active operation through the use of a diversion constructed above the highwall. While conditions suitable for use of this method are limited, there are some cases where it can be used successfully.

During mining care should be exercised in leaving several feet of the "blossom" or "bloom" coal undisturbed. This low quality, weathered coal nearest the outcrop is seldom marketed. If the zone remains undisturbed it will serve as a barrier to subsurface water movement and will result in improved spoil stability.

During Reclamation

Proper drainage is essential before, during, and after any mining operation. Improper drainage has inflicted more damage than any other one factor associated with strip mining. Improper drainage has caused the disturbed overburden to be carried down the mountainsides and into the streambeds below. Improper drainage can force the flow of water into the highwall where it comes into contact with the coal face thus creating conditions favoring acid water formation.

Regrading of the spoil after mining or as mining proceeds is generally accepted as a standard reclamation procedure. In fact, much of the current reclamation legislation is leaning toward complete regrading to original contour.

Backsloping

Drainage control may be accomplished during the regrading phase. Two aspects of the drainage control problem must be recognized. First is surface runoff from the bench. Serious erosion occurs when runoff water concentrates on the bench and is permitted to flow onto spoil outslopes. This can be controlled by back sloping the benches toward the highwall.

Bench Drainage

The second part of the problem involves removing water from the bench. This is generally accomplished by making a bulldozer cut through the spoil bank at intervals around the strip and draining accumulated water off the bench and onto the fill.

Channel gradients around the bench at the base of the highwall are generally moderate. However, at drainage points the gradient greatly steepens and as a result large gullies are eroded on the side of the fill.

Various protection measures for control must be used. One measure is to drain pits on the bench into natural drainage-ways where stream channels are gentle. Another is to slow down bench discharge by a series of check dams and to limit the maximum discharge rate by installing a fixed-diameter culvert. A third method is to protect the steep drainage channel with rock riprap, concrete, or other structures and install energy dissipators at intervals down the channel.

Impoundments

Much erosion and subsequent sedimentation can be eliminated by controlling storm runoff. When storm runoff is held in a pit or pond, most of the sediments will be trapped. When runoff is allowed to flow freely, much more sediment will be dumped directly into streams.

Ponding of water on contour strip mines remains a controversial subject. While impoundments are desirable from the standpoint of sediment and direct runoff reduction, storage of large volumes may present serious safety hazards. Seepage from ponds may lubricate the spoil and result in failure of banks that otherwise might have remained stable.

Due to the controversial nature of impoundments on contour benches, ponds should not be encouraged until criteria are available for adequate design, location, construction, and maintenance.

Some type of silt basin can be used effectively on contour strip mines. For example, on ridges or knolls where the entire overburden is removed in getting at the coal, basins have been designed and constructed for the purpose of trapping eroded material and preventing it from reaching streams below. Spillways have been constructed so that, if the basins ever become filled, drainage will be directed to an undisturbed point on the ridge. This represents the greatest distance from natural stream channels and will allow maximum time for infiltration and percolation into the natural soil mantle.

Reclamation by inundation may be done on some surface-mined areas, depending upon the quality of water flowing into the impoundment. If this

inflow is not acid, then impounded water can neutralize any residual acid formation. A permanent pond of water over acid-bearing materials will prevent oxidation and reduce further acid production.

Improvements in the quality of impounded waters flowing from acid spoils have not always resulted. While pH has not always shown marked improvement, there has commonly been significant reduction in total acidity and iron. Even in less satisfactory cases, the drainage has had a less deleterious effect on downstream water quality than that from unreclaimed areas.

Diversion

The diversion of water from the mine area and from exposed acid-producing materials is an abatement technique that can be used in surface mines. Surface diversion of runoff may involve the construction of drainage ditches.

On areas that are not too stony, erosion can often be controlled by means of diversions. A diversion is a channel constructed across the slope, with a supporting ridge on the lower side. Diversions break the slope length and remove surface runoff to safe outlets. They are constructed on a continuous grade of one-to-two percent to prevent impounding of water. The depth and width may vary depending upon slope and land use. Diversions should be constructed only on settled spoil and should be seeded to an adequate grass or grass-legume mixture.

Terraces

Terracing is another means of erosion control which can be used effectively on strip-mine spoils. A terrace is a ridge or channel (or both) constructed in earth to hold back surface runoff or to convey it safely off an area. A water-holding or absorption-type terrace has no grade and is designed to store surface runoff. This type may be used on spoils that are highly permeable, so that water held behind the terraces seeps into the spoil.

Terraces used on strip-mine spoil banks should be spaced close enough to provide storage for expected runoff on the slopes. Terraces can be constructed with bulldozers, motor graders, or with special equipment designed for that purpose.

Vegetation

Perennial grasses and legumes have a remarkable ability to reduce runoff and to prevent erosion once they are established, and revegetation has long been recognized as a means of erosion control on spoil banks. Two types of seeding are recommended. A quick-growing cover of herbaceous species will provide temporary cover essential for initial protection against erosion. More permanent types of cover should be seeded or planted on those areas where additional protection is needed for a period of more than one or two years. Species and seeding recommendations are discussed in another section of this report.

Soluble Salts

On surface-mined lands and especially on those mined for coal, the freshly exposed spoil weathers quite rapidly releasing large quantities of soluble salts. Many of these salts are toxic to plants and aquatic organisms and may do considerable damage to streams.

Acid is produced from the breakdown of the sulfur compounds contained in pyrite and marcasite. The amount of these compounds varies between spoils and may frequently be confined to certain geologic strata in the overburden.

Here, again, the best way to handle the acid mine drainage problem is through preventive measures. These include the recognition of pyritic materials in the overburden and burial of toxic strata during mining. Getting a vegetative cover on spoils as soon as possible may be a factor in hindering acid production.

Once acid reaches the streams, treatment becomes more expensive. Limestone placed in streams will neutralize some acid. Limestone may be placed in a drum which is rotated by the flowing stream. In this way the limestone is agitated and is dissolved in the stream.

Lime may be added to the acid water and the solution passed through a pond or lagoon. If this method is used the lime may be fed as a lime-water mixture or slurry or as a dry chemical. Approximately three-fourths ton of hydrated lime is necessary to neutralize one ton of sulfuric acid.

Lime neutralization is perhaps the most common method of treating acid mine drainage. However, a number of other methods have been or are undergoing tests. These have been reported by the Federal Water Pollution Control Administration, currently in the Environmental Protection Agency.

Since there is a finite amount of potential acidity in any spoil bank, rapid leaching of this material should minimize the length of time during which it will have an impact on the water resource, providing erosion is prevented. If erosion is not prevented, continual exposure of fresh, relatively unweathered spoil will prolong acid and soluble salt production.

Mining and reclamation should be carried out with the objective of preventing acid formation. If this is not done and streams become polluted with acid and other soluble salts, it may be necessary to treat the water for many years beyond completion of mining. Then it becomes more difficult. So, the best treatment is prevention.

REVEGETATION

Purpose

Revegetating spoil banks formed by the surface mining of coal is important for (1) reducing stream pollution caused by erosion and sedimentation, (2) restoring the disturbed land to a productive use, and (3) improving the aesthetics of the disturbed landscape. Erosion of barren spoil banks is especially troublesome in the Appalachian region because much of the surface mining occurs on steep mountain slopes. The most important reason, then, for revegetating surface-mined lands in Appalachia is to retard runoff and erosion from the surface of spoil banks.

Because the natural vegetation of most of the Appalachian region is forest, much of the surface-mined area has been planted to trees and eventually will be reforested. Some of the surface mined lands will be revegetated primarily for other land uses. But regardless of the intended land use, the appearance of any disturbed land is greatly enhanced when covered with vegetation.

Spoil Properties Affecting Plant Establishment

Chemical

Some spoil banks are difficult to revegetate because of their unfavorable chemical properties. Properties that hinder the establishment and growth of plants include nutrient deficiencies, toxicities, and imbalances. The nature of the overburden and the acidity that develops as spoil weathers generally determines whether a spoil bank will be a favorable or unfavorable

medium for plant growth. If spoil contains a high percentage of pyritic materials, sulfuric acid is produced which lowers spoil pH, thus altering the availability of plant nutrients. Very acid spoils are not only difficult to revegetate, but growth is usually poor once vegetation is established.

The nutrients commonly deficient in spoil materials are nitrogen and phosphorus. Nitrogen is low in most spoils because in stripping operations the topsoil and litter layer are removed. Available phosphorus is often low in spoils for several reasons. First, rock strata in the overburden sometimes contain only small quantities of phosphorus-bearing minerals. Secondly, there is no reservoir of organic phosphorus compounds, and thirdly, the phosphorus compounds produced at the low pH common in many spoils are relatively insoluble.

Toxic levels of some elements occur in most very acid spoils. At low pH ranges, aluminum and manganese are brought into solution in quantities that interfere with plant establishment and growth. The rapid weathering of rock fragments in spoil banks, while providing an adequate supply of some plant nutrients, may aggravate toxic effects of other nutrients, especially under acid conditions. Nutrient imbalances, especially between calcium and magnesium, occur in some spoils. Such an imbalance results from the mineralogical composition of the rock strata in the overburden.

High salt concentrations in spoils can be detrimental to seed germination and plant establishment. In very acid spoils, accumulation of salts is often visible on the spoil surface.

Physical

The physical characteristics of mine spoils as a rooting medium for plants are quite different from the physical characteristics of a naturally developed soil. Spoil is a heterogeneous mixture of rock fragments and soil-sized material derived from any or all the strata in the overburden. In the Appalachian region, overburden consists mostly of shales, siltstones, and/or sandstones. The thin layer of top soil and the litter are usually buried at the bottom of the piles.

Physical properties of spoils generally present less of a reclamation problem than do chemical properties. Nevertheless, establishment of vegetation is often adversely affected by spoil physical properties.

The particle-size distribution, or texture, of spoils influences vegetation mainly through its effects on spoil moisture. The coarse texture of most spoil surfaces, while providing abundant microsites for germination of seed, tends to promote rapid drying in hot, dry weather. Yet, adequate moisture may be available a few inches below the surface because generally there are no continuous water columns extending to the spoil surface. Thus, timing of revegetation efforts is of critical importance since germinating seed and young seedlings require available moisture at the spoil surface. Once plants are established, roots can absorb moisture from lower depths in the spoil where moisture is usually available. Spoil surfaces that contain some soil-sized material to retain moisture, plus larger fragments to provide micro-relief, generally are more favorable seedbeds than spoils of uniform texture.

High temperatures at the spoil surface can reduce and delay seedling emergence and alter growth rates of surviving plants. Temperatures in excess of 150°F have been recorded on spoil surfaces composed of dark shales. Solar insolation is especially intense on southern and western exposures and prolonged periods of exposure to high temperatures can be lethal to young plants.

Frost heaving occurs more readily in spoils than in natural forest soils because of the absence of the insulating effect of the litter layer. Frost heaving during late winter and early spring acts as natural seedbed preparation and, as such, is beneficial for seed germination. On the other hand, repeated frost heaving can dislodge planted seedlings and expose roots to desiccation.

Biological

Microorganisms are an essential component of soils and no doubt also play an essential role in successful revegetation of mine spoils. Chemical and physical properties of soil greatly influence the dynamics of the microorganism population and the effect of that population on its environment.

Since the litter layer and topsoil are usually buried during the mining operation, spoil organic matter is essentially nil. Thus the energy source of much of the microorganism population is greatly reduced. In addition, the extremely acid conditions found in some spoils favor acid-tolerant organisms, such as the mycorrhizal fungus Pisolithus. Consequently, the

diversity of microorganisms in spoil is reduced as compared to natural soils.

In spoils, as well as in soils, nitrification (conversion of ammonium to nitrate) is greatly inhibited at low pH. Ammonification (conversion of nitrogen in organic form to ammonium) is accomplished by several groups of organisms, some of which are active under acid conditions. The ability of pines to utilize the ammonium form of nitrogen may explain the natural invasion of some species of pine and the good growth rates of some pine plantations on acid spoils.

Workers in West Virginia have found that the bacterial density of vegetated spoil banks is as high as in undisturbed soil. Spoil under black locust contained more bacteria than spoil under pine, but both types had fewer bacteria than spoil vegetated with grasses and legumes. However, spoil under the pine plantation supported greater populations of fungi and actinomycetes than spoil from the black locust planting.

From soils studies, it is known that certain non-symbiotic nitrogen-fixing bacteria, especially Azotobacter, are sensitive to high H-ion concentration. Generally, symbiotic nitrogen-fixing bacteria also are sensitive to high acidity. However, there are strains of Rhizobium which tolerate acid soils and this probably contributes to the acid tolerance of the host plant. Thus, it may be possible to select strains of Rhizobium for acid tolerance. These strains could then be used for inoculum for legumes seeded on acid spoils.

The importance of soil fauna in the revegetation of spoil banks has received little consideration. Recent research in Ohio shows that earthworms added to vegetated spoil hastened the decomposition and incorporation of plant litter. In addition, the availability of nutrients, especially phosphorus, was increased by earthworm activity. Much more research is needed on the speed of immigration of soil fauna into strip-mined areas and their subsequent effect on breakdown of litter and nutrient cycling.

Classification of Spoil

Bituminous strip-mine spoils have been classified in a variety of ways. Three criteria--acidity, slope, and stoniness--are most useful because these factors usually exert a dominant influence on vegetation.

Acidity, either through direct or indirect effects, is a major factor limiting plant survival and growth. Spoil material is grouped into four classes on the basis of the percentage area falling within various pH (acidity index) ranges.

Slope steepness limits land use and machinery operation. A slope of 25 percent is maximum for hayland or contour operation of machinery.

Stoniness also limits land use and the operation of mechanical equipment on spoils. Spoil banks are divided into two classes: (a) non-stony--will not interfere with seedbed preparation nor limit the use of mechanical tree planters, and (b) stony--surface or buried stones restrict seedbed preparation, but will not restrict tree and shrub planting by hand.

Anthracite strip-mine spoils have been classified into four types based primarily on the petrographic nature of the overburden. Other factors including stability, color, aspect, and location, in addition to the previously mentioned criteria, may be considered for special reclamation uses.

Improving Problem Spoils

Generally, vegetation can be established rather easily on spoil banks that are not strongly acid, especially if fertilizer is applied. Thus every effort should be made to place non-toxic material on top of the spoil bank. The identification of toxic and non-toxic spoil material is most easily accomplished by a simple pH measurement--a measurement of the H-ion concentration in a spoil-water mixture. The H-ion concentration probably does not affect vegetation directly since plants can withstand a wide range of pH when other factors are favorable. Instead, the effect of the H-ion concentration is probably through the many indirect effects on nutrient availability. At low pH (below 5.0), aluminum and manganese availability may increase to the point of toxicity. In addition, phosphorus deficiency may limit plant growth. These, and other pH-related phenomena, likely explain the often-observed correlation between pH and plant growth.

Prediction of the pH after various strata in the overburden have been converted to spoil would be desirable. Then spoil from strata that would weather to non-toxic material could be separated and stockpiled during the mining operation and finally placed over any toxic material. In instances

where the overburden is composed entirely of potentially toxic strata, or where steepness of terrain prohibits separation and stockpiling of toxic and non-toxic materials, strip-mining permits could be prohibited to protect the environment. However, it is difficult to predict the lowest pH that will develop because spoils containing large quantities of sulfide minerals may take months to develop their lowest pH. Correlation between chemical properties of the overburden and chemical properties of spoil must await further research.

Many field plots in eastern Kentucky have indicated that plant establishment and subsequent growth on spoil banks is enhanced by fertilizer applications. In no cases were fertilizer applications detrimental to plants. As has been mentioned, nitrogen is nearly always low in spoil materials. However, many times there is no response to nitrogen applications until phosphorus is also applied. Furthermore, the application of phosphorus alone is essential before any growth is possible on some spoils. Supplementing phosphorus with nitrogen usually produces an additional growth response on most spoils.

Phosphorus applications probably enhance plant growth on acid spoils in two ways. Available phosphorus may be increased to above growth-limiting levels and, toxic levels of some elements may be reduced to more tolerable levels through precipitation as relatively insoluble phosphate compounds. The beneficial effect of nitrogen applications probably is the result of

increasing spoil supplies of the element to above growth-limiting amounts rather than through any indirect effects on other soil factors. No plant responses to potassium applications have been observed on spoil banks.

Despite the fact that only a small percentage of spoil banks in Appalachia are used for agricultural purposes, fertilizer application of phosphorus and nitrogen are recommended for all spoil banks. The beneficial effects of fertilizer on establishment of plant cover are ample reasons why fertilizer should be used. While the rates of fertilizer to apply will vary from spoil to spoil, we have found that about 50 pounds of nitrogen and about 100 pounds of phosphate (P_2O_5) per acre, applied at the time of seeding or planting, are usually helpful in establishing initial plant cover.

Very acid spoils (pH 3.5-4.5) usually require lime application before vegetation can be established. Not only does lime supply an essential plant nutrient (calcium), but, more importantly, the rise in spoil pH after lime application reduces toxic levels of aluminum in solution. Furthermore, manganese uptake by plants is reported to be reduced after lime application. Large quantities of lime (10 ton/acre, or more) may be required on very acid spoils. Furthermore, repeated application may be required to maintain vigorous vegetative cover if the spoil material is high in pyritic minerals. Rates of lime to apply can be determined by spoil tests and must be based on an analysis of total acidity, rather than on pH. Even total acidity analyses

may underestimate lime requirements because potential acidity (unoxidized sulfides) will become actual acidity as the spoil weathers.

The use of mulches as spoil amendments has been largely overlooked. Recent experiments in Pennsylvania have indicated that shredded-bark mulches do aid in establishing a vegetative cover on some spoils. Beneficial effects of bark-mulches are probably both physical and microbiological. Physically, strips of bark help hold seed in place until germination can occur. Also, a bark mulch reduces evaporation from the spoil surface, thereby aiding in maintaining a favorable moisture supply and preventing the accumulation of toxic salts. Microbiologically, bark mulches provide an organic energy source that probably benefits the spoil microorganisms.

In most cases no special physical preparation of the spoil surface is necessary following rough grading, provided seeding and planting follows shortly thereafter. After rough grading the spoil surface is generally loose and varied in microtopography, and sufficient microsites for germination are available. However, if the spoil surface becomes compacted, either by machinery or through natural weathering, it may be necessary to scarify the surface with a disc harrow or to apply an organic mulch to improve physical seedbed characteristics.

Establishing Herbaceous Vegetation

Herbaceous vegetation (mainly grasses and legumes) plays an important role in surface mine reclamation primarily for establishing a quick, protective plant cover on barren spoils. Even where reforestation is the ultimate goal in reclamation, grasses and legumes are needed for site protection until the trees are developed enough to provide the necessary protection. On mine spoils suitable for agricultural or other special uses, establishing a grass and legume cover often will be the primary goal in reclamation.

Adaptation of Species

To be most effective for erosion control and watershed protection the herbaceous vegetation should be established as quickly as possible after the mining operations are completed. Part of the problem is finding the plant species best adapted for this purpose. Experience and research have proven that there is no "magic" species that will establish quickly in every kind of spoil and climatic environment. Field and greenhouse studies show that some species, or varieties of some species, are better adapted than others to various adverse spoil and environmental conditions.

Some spoils in parts of Appalachia will support most of the grasses and legumes used locally for pasture or hayland. A few of these spoils are so favorable for plant growth that the yield and quality of forage equal or exceed

that grown on adjacent unmined agricultural soils. Generally, such spoils are slightly acid to mildly alkaline (pH 6.0-7.8), contain adequate amounts of plant-available phosphorus and potassium, and texturally are composed of a higher than usual amount of soil sized particles. On spoils of this nature grasses and legumes are often established without soil amendments or fertilizer.

Unfortunately, most of the coal mine spoils in Appalachia are not as favorable for plant growth as those just described. Many are acid, phosphorus deficient, and texturally less desirable for good plant growth. Yet, even on many of these spoils, certain species of grasses and legumes make good growth. Many of the cool-season grasses used for forage on farms within the region grow reasonably well in most spoils with pH as low as 4.5. Some of these grasses are K-31 fescue, perennial ryegrass, orchardgrass, redtop, and tall oatgrass. However, the most acid-tolerant and most versatile grass for providing quick cover on a wide range of spoil conditions is weeping lovegrass. It is a warm-season grass that will grow well in spoils with pH as low as 4.0. Weeping lovegrass has been successfully used for quick cover on spoils in Appalachia as far north as Pennsylvania, but is adapted better to the southern two-thirds of the region.

Results of six years of research on species adaptation have shown that weeping lovegrass will provide more ground cover in the first growing season after seeding, and over a wider range of spoil conditions, than any

other species tested. This was especially important on extremely acid spoils (pH 4.0-4.5) where weeping lovegrass often made a satisfactory ground cover (60%-90%) in one growing season whereas most other species made little or no cover. With more favorable spoil (pH 4.5 and higher) and a cool, wet summer, fast-growing cool-season grasses like annual and perannial ryegrasses sometimes provide effective cover faster than weeping lovegrass. But, in relatively dry years, weeping lovegrass was better adapted to the droughty environment that occurred on spoil banks in late spring and summer.

Normally, herbaceous species are sown on spoil banks in late winter and early spring, and sometimes in the fall of the year, because weather and spoil moisture conditions are more favorable in late spring and early summer for seedling establishment. However, cover can also be established by sowing summer annual grasses such as pearl millet and sudan X sorghum hybrids. These annuals provide only temporary cover, therefore permanent-cover perennial species must be sown either along with the annuals or in a separate seeding the following fall or spring.

Generally, most legumes are less tolerant of acid spoil than grasses. Many of the forage legumes such as alfalfa, red clover, ladino clover, crown vetch, and sweet clover usually grow poorly in spoils that have a pH below 5.5. Two perennial legumes, sericea lespedeza and birdsfoot trefoil, are especially useful for sowing on surface-mine spoils because they grow well where pH is as low as 4.5. Sericea lespedeza is a warm-seasom legume

that is used on spoils throughout much of the Appalachian region although it is best adapted and grows most vigorously in the southern half of the region. Trefoil is a cool-season legume and is better adapted to the northern half of the region.

Two summer annual legumes, Korean and Kobe lespedezas, are valuable for providing ground cover during mid- to late-summer. The Kobe is more tolerant than Korean of the high manganese content often found in acid spoils. Both species grow best in the southern half of the region.

Fertilizer is essential for the quick establishment and good initial growth of all herbaceous species. Nitrogen fertilizer is nearly always needed, especially for the grasses. Many spoils also should be fertilized with phosphorus for satisfactory growth of grasses and legumes. Legumes are of special value in revegetating mine spoils because, when properly inoculated, they develop nodules on their roots through which nitrogen in the air is converted to a form of nitrogen that can be used by plants. Thus, once the legumes are established, nitrogen fertilizer is not essential for their continued growth, but it does aid in the rapid establishment of legume seedlings. On phosphorus-deficient spoils applying phosphorus fertilizer is essential for both the establishment and growth of legumes.

Deep-mine spoils in the Anthracite Region of Pennsylvania are extremely difficult to vegetate with grasses and legumes. Most of the spoils are extremely acid and dark-colored and should be limed and mulched before trying to establish herbaceous plants. Attempts to establish crown vetch from seed

on Anthracite breaker refuse failed even with liming, mulching, and fertilizing. However, planted crowns of this legume did survive and make limited growth on limed areas.

Herbaceous Mixtures

For maximum protection of disturbed watersheds, herbaceous seedings should include species capable of providing both quick cover and long-term or permanent cover. Two or more species are required because, usually, those species that provide quick cover are short-lived, and those that provide long-term cover are slow in becoming established. Ideally, the quick-cover species will provide the desired ground cover in the first growing season but will not choke out the seedlings of the long-lived species that are struggling to get established. Then, by the second and third growing seasons, the permanent species will become dominant.

Legumes should be included in all mixtures, because once established they provide the nitrogen necessary for their continued growth and growth of companion grasses. Generally, grasses should be sowed with the legumes because grasses usually provide protective cover more quickly than legumes. Also, grasses are fibrous rooted and tie down the spoils a little more effectively than the tap-rooted legumes, especially in the first few years after seeding.

The degree of spoil acidity (pH) can determine the choice of legume used in a mixture. However for general use over the widest range of spoil

conditions, a mixture of sericea lespedeza, K-31 tall fescue, and weeping lovegrass is recommended for the southern two-thirds of the Appalachian Region. For the northern one-third of the region, birdsfoot trefoil is recommended in place of sericea lespedeza.

In herbaceous mixtures, compatability between the quick cover species and the slower-developing permanent species is important. Weeping lovegrass is a desired quick cover species because usually it is not too competitive with the slower-developing fescue and legume. Perennial ryegrass is a short-lived grass which can be used for quick cover in place of weeping lovegrass. However, perennial ryegrass is usually more competitive than lovegrass with the other species in the mixture. Annual ryegrass is even more competitive than perennial ryegrass.

The season in which the vegetation is to be established will also influence the species used for quick cover. For establishing quick cover in the fall, winter annuals such as ryegrass, cereal rye, or winter wheat are useful. Perennial ryegrass and weeping lovegrass are useful for seeding in early spring. With exceptionally favorable growing conditions, K-31 fescue and orchardgrass will also provide reasonably quick cover. For establishing quick cover in late spring and during the summer, weeping lovegrass, Korean and Kobe lespedezas, pearl millet, or sudan X sorghum hybrids often prove satisfactory.

Regardless of when the seedings are made, perennial long-lived species must be included for permanent site protection. On spoils with pH of 5.5 or higher, crown vetch will make excellent permanent cover but is very slow to get started. Weeping lovegrass is a good quick cover plant to seed with crown vetch in the spring.

Methods of Establishment

Factors contributing to the difficulty in establishing herbaceous vegetation on surface-mined areas include limited or no access to spoil banks, configuration of spoil banks especially steep outslopes, and unfavorable seedbed conditions. Thus, the circumstances surrounding each situation where seeding is required will determine the best method to use in trying to establish vegetation.

The most common method of seeding grasses and legumes is broadcasting or spreading the seed over the surface of the spoil. Types of equipment that are available for broadcasting seed vary from small cyclone seeders to seeding attachments on airplanes and helicopters. The size of the area to be seeded and accessibility usually determine the type of seeder used. A very small area can be seeded by one to several persons using a hand-operated cyclone seeder. A larger area that is accessible by motor vehicles, and easily traversed by them, can be seeded with large power driven cyclone seeders mounted on or pulled by a vehicle. The main disadvantage of cyclone seeders is that they are incapable of throwing seed any great distance from the

machine. Even if driven close to the edge of an outslope, the seed and fertilizer will be spread only a short distance down on the slope.

Another machine recently designed in Kentucky for spreading large quantities of seed, fertilizer, and lime is a blower mounted on the back of a conventional lime-spreading truck. This machine can blow the seed and other material onto areas such as highwalls or outslopes that cannot be traversed by the vehicle. The truck itself requires a roadway or relatively smooth surface for traveling on the mined area, the same as any rubber tired vehicle used to transport seeding equipment.

The West Virginia Agricultural Experiment Station has developed a fertilizer spreader that uses a continuous belt system in place of the conventional spinner system. This machine throws a fairly uniform pattern of fertilizer out to about 60 feet on the level. It shows promise for use on outslopes of spoil banks.

One of the more popular pieces of equipment for broadcasting seed, fertilizer, lime, and certain mulches is the hydraulic seeder, more commonly called the hydroseeder. This machine consists mainly of a large tank with a high pressure pump for spraying a mixture of water, seed, fertilizer, etc. onto the land. The hydroseeder unit can be mounted on a truck chassis or pulled on a trailer. The aqueous mix can be spread a distance of 75 to 200 feet from the vehicle depending upon the size of the unit. This is advantageous for seeding outslopes and highwalls. Disadvantages are (1) that a source

of water is required which is not always available on surface-mined lands; and (2) most of the weight of a full load is water--only a small portion is payload, i.e. seed and fertilizer. Consequently, only a relatively small area can be covered with each load.

Where a large number of acres need to be seeded and accessibility for vehicles is poor, aircraft seeding, especially by helicopter, appears to be the most practicable method. In addition, aircraft can be used when spoils are too wet and muddy for the use of a land vehicle. A large area can be seeded in a short time, thus taking advantage of favorable seedbed conditions when they exist.

Seeding by aircraft also requires some special preparations and equipment. A landing field for fixed wing aircraft or heliport for helicopters should be located as near as possible to the area to be seeded. The field or heliport must be easily accessible to vehicles bringing in loads of seed and fertilizer. A wide bench of a nearby strip mine may serve the purpose. Because large amounts of seed and fertilizer are normally involved with aircraft seeding, special mixing equipment may be required to blend the several species of seed or several kinds of fertilizer. Mixing seed with fertilizer and spreading both at the same time has been practiced on several large-scale seeding operations.

One of the basic requirements for successful plant establishment is sowing the seed on a favorable seedbed to assure proper coverage of most of

the seed. Ideally, seed should be sown on freshly graded spoils because, generally, they are ready-made seedbeds which require no further preparation. Another favorable situation is seeding in late winter and early spring when the spoils are loosened and heaved by frost action. However, it is sometimes difficult to get onto the spoils with heavy vehicles at that time of year. Seeding with aircraft may then be most practicable if the area is large enough for contracts at low cost-per-acre application rates.

If seeding on freshly-graded spoils or on frost-heaved spoils is impossible and spoil surfaces are crusted over, then seedbed preparation is necessary. This is especially important for seedings made in late spring, summer, and fall. Preparing a seedbed requires tilling or scarifying the spoil surface with equipment such as a disc, harrow, or ripper. Seed can be broadcast either ahead of or behind the tillage operation. It is important to cover as much of the seed as possible with a light covering of spoil, but to avoid burying the seed too deeply--a problem that may occur if seed is broadcast ahead of tillage. It is recognized, of course, that such a tillage operation is limited to the less steep areas and to spoils smooth enough to be traversed by the appropriate equipment.

Using a grain drill, grass drill, or special heavy duty drill is an even better method of planting seed on crusted spoils that can be traversed with farm equipment. Ordinarily a tillage operation ahead of the drill is not required. Seeding rates can be greatly reduced with drilling as compared with broadcasting because nearly all of the seed is properly planted and covered.

Planting of Trees and Shrubs

Most of the reclaimed strip-mined land in Appalachia has been planted to trees. There are several reasons for this. Trees can be planted on most stripped areas regardless of the type or quality of the back-grading job. Trees also tolerate a wider variety of spoil conditions than most grasses and legumes. On favorable spoils, trees may produce a variety of valuable products, including pulpwood, poles, and sawtimber, in addition to providing aesthetic and wildlife values. On poorer spoils, trees (if they survive) provide long-term site protection where other plants will not grow. Some spoils are now growing Christmas trees.

Many shrubs are preferred species for wildlife. Several species produce abundant fruit and provide cover for many kinds of wildlife, especially when legumes are planted in alternate strips. The high cost and limited availability of shrub seedlings, however, may restrict their use to areas that will be managed especially for wildlife.

Species

Most spoils fall within a tolerable acidity range for conifers, pH 4.0 to 6.0. Studies indicate that conifers can mature and produce commercially valuable timber on some spoils. On Pennsylvania bituminous spoils, Scotch, red, white, jack, pitch, and Austrian pines have proven suitable for planting. Norway spruce and white spruce provided little initial site protection because of their slow growth, even though their survival rates were adequate.

Red pine is recommended only for areas where European pine shoot moth is not prevalent.

On anthracite spoils in Pennsylvania, jack, red, Scotch, and pitch pines generally had better survival than white, Virginia, and Austrian pines. Best growth was obtained with Virginia pine, followed by jack and Scotch pines.

Japanese and European larches have survived adequately and grown relatively well on both bituminous and anthracite spoils in Pennsylvania.

In Kentucky, Virginia pine appears to be the most acid-tolerant conifer and has survived with pH slightly below 4.0. However, on better spoils loblolly, pitch, or pitch-loblolly hybrids probably outgrow Virginia pine. White pine, although its survival is generally satisfactory, is a very slow grower during its first few years and offers little site protection.

Among hardwood species, hybrid poplars have performed better on Pennsylvania spoils than have European alder and black locust. Recent studies in that state have indicated that European white birch and gray birch can withstand and make better growth on very acid sites than even acid-tolerant conifers. Bristly locust is another hardwood species that has shown promise in Pennsylvania for erosion control. Plantings of this species on spoils indicate that it sprouts vigorously from exposed roots. In Kentucky, European alder appears to perform as well as black locust on acid spoils. Hybrid poplar also grows well on some Kentucky spoils, and even such bottomland

species as sycamore, sweet gum, and cottonwood are found on spoils that are not toxic and contain adequate moisture.

Wildlife plantings of shrubs in conjunction with tree species are desirable, especially on poorer spoils that are unlikely to produce rapid tree growth. Planting shrubs in intervening strips and along borders between stripped and unstripped lands provides a variety of cover types and food sources beneficial to wildlife. Recommended shrub species include autumn olive, multiflora rose, bicolor lespedeza, silky dogwood, bristly locust, arrowwood, and mugho pine.

Methods of Establishment

There are two ways of establishing trees and shrubs on spoil banks, direct seeding and planting seedlings. Direct seeding has not been very successful in the past; the chemical and physical characteristics of spoil surfaces often inhibit seed germination. However, recent studies in Alabama and Tennessee indicate that direct seeding of southern pines to fertilized spoil banks can produce adequately stocked stands. Fertilizing direct-seeded black locust in Kentucky, while not significantly increasing the number of seedlings surviving after one year, did greatly increase growth. Direct seeding, in conjunction with fertilization, has produced good stands of bicolor lespedeza in Kentucky. Direct seeding of trees and shrubs offers many practical advantages over planting on steep slopes, but more research is needed to insure success of the technique.

Combination Plantings of Woody and Herbaceous Materials

Trees alone planted on surface-mined land do not provide erosion control in their early years of development. Therefore, establishment of a herbaceous cover with tree planting is desirable and recommended on many spoil banks in Appalachia.

In combination plantings, the herbaceous vegetation will affect the growth and survival of the tree seedlings. Growth, especially of hardwood seedlings, is greatly retarded in a dense stand of grasses and legumes; initial survival is not severely affected. Growth of pine is less severely affected, provided the pine survive through the first growing season.

The decision to seed or not seed herbaceous species with trees should be determined primarily by the need for immediate site protection. If site protection is not critical, maximum tree survival and growth can then be the primary objective in reclamation planning. For example, on a bench with grading designed to control runoff and drainage, trees can be planted alone without competing herbaceous cover; however, the contiguous outslope should be planted with trees and sowed with herbaceous vegetation and fertilized to obtain maximum ground cover.

Some species of grasses and legumes are more competitive than others with trees. When black locust is seeded with herbaceous vegetation, the herbaceous species that make rapid growth early in the spring, such as rye-grass, retard the growth and survival of black locust seedlings more than do

species such as weeping lovegrass and Korean lespedeza that make their major growth in late spring and summer. Thus, if both ground cover and good tree survival and growth are needed, the herbaceous species least competitive with trees should be used. Furthermore, only enough nitrogen fertilizer should be applied to allow a moderate growth of grass. The amount of phosphorus fertilizer used should depend on the level of plant available phosphorus in the spoil.

Another approach to establishing both trees and herbaceous cover on the same area is sowing a band of herbaceous cover between the rows of planted trees. This works best on areas that can be traversed with farm machinery. Mechanical tree planters can be used for planting trees and a grain drill or grass seeder can be adapted for sowing a narrow band of grass between the rows of trees. Ideally, by the time the grass or legume spreads into the rows of trees, the trees will be large enough to withstand the competitive effects of the grass.

Combination plantings of herbaceous materials and shrubs are very desirable for wildlife cover and food. Grasses like switchgrass, and legumes such as the clovers and lespedezas, produce seed for song and game birds. Shrubs like autumn olive, bicolor lespedeza, tartarian honeysuckle, and silky dogwood provide both fruit and browse for many creatures of the wild.

Combination plantings of trees with nitrogen-fixing shrubs promise to improve the growth of desirable tree species. Shrubs such as autumn olive

or bicolor lespedeza should be planted in alternate rows with the trees. An advantage of using shrubs like autumn olive (instead of trees like black locust) as nurse plants is that the shrubs will not overtop the slower growing commercial tree species.

RECLAMATION FOR SPECIAL USES

Strip-mined lands may be reclaimed for many special uses. These lands may be used for woodland, wildlife, cropland, recreation, and sanitary fill, as well as for housing and industrial sites. For each use certain factors must be considered and specific treatments should be included in the reclamation plan.

Woodland

Since much of the area strip mined in Appalachia was in forest cover, reclaiming mined land for woodland should receive important consideration. Trees grow on a wide range of spoil conditions and can provide timber products as well as permanent cover.

Developing strip-mined areas for woodland requires little beyond basic reclamation. It is necessary to select species which are capable of yielding the desired crops according to site conditions. Area stripping creates large blocks that can be managed efficiently for pulpwood production. Several contour strip mines may have to be combined to provide sufficient area for economic management. The bench portion is usually easily negotiated by logging equipment, and many trees growing on the upper portion of outslopes are also within easy reach of equipment operated on the benches. If woodland above the strip mines is to be included in the management unit, roads to provide access to these areas should be constructed during reclamation.

Tree growth is sometimes reduced by competition from heavy herbaceous growth. On areas designated for wood products, only enough herbaceous cover to control erosion should be established. Where both trees and herbaceous cover are desired, competition from grass can be reduced by lowering the rate of seeding and applying the minimum amount of fertilizer needed to establish grass cover.

Mined areas can be used for growing Christmas trees. Spoil materials generally fall within the acidity range appropriate for conifers. Physically, spoils are well drained and offer good support so vehicles can operate adequately during the late fall harvest period and throughout the spring planting season. Most spoils resist invasion of herbaceous plants. Thus costly mowing operations usually associated with Christmas tree establishment can be reduced or eliminated altogether. Naturally, herbaceous cover should not be seeded in areas reserved for Christmas tree production.

Coal-haul roads built to bear heavy coal trucks make acceptable logging roads. Of course, they must be maintained to provide continuous access for plantation management and fire protection. Broad, level benches can be cleared for yarding areas or even as sites for small sawmills.

Wildlife

Strip-mined areas are especially well suited to wildlife development. These areas can be developed for wildlife alone or integrated with other types of plantings to provide multiple-use cover.

The grasses, legumes, trees, and shrubs useful as wildlife food and cover will grow on a wide range of spoil conditions. Legumes are especially desirable because of their seeds. Lespedezas, birdsfoot trefoil, crown-vetch, and clovers grow well on some spoils. Shrubs such as autumn olive, bristly locust, honeysuckles, dogwoods, and multiflora rose are beneficial to wildlife and are suitable for planting on mine spoils. Coniferous trees are more desirable for cover than hardwoods, but a mixture provides a maximum of food and cover.

The cost of reclaiming strip-mined land for wildlife use depends primarily on how intensively the area is to be developed and managed. Border plantings substituting shrubs for trees can be done with little additional cost. If food strips of corn, wheat, or other grain are established on benches, these areas may require additional lime and fertilizer, and the spoil will have to be tilled.

Small ponds can be left on benches for watering of game and resting areas for migrating waterfowl. Area-type stripping provides more opportunity for construction of larger lakes for nesting of waterfowl.

Stocking of larger lakes with game fish can be done where water quality meets the requirements of the species. Water should be sampled before stocking and checked periodically to make sure quality is being maintained. State fisheries personnel should be consulted for assistance in developing areas for fishing lakes.

Access roads should be maintained for sportsmen and for management purposes. Local safety and liability laws should be checked because these vary from state to state.

Agriculture

A relatively small acreage of the surface-mined area in Appalachia has been reclaimed for agricultural uses. The potential of any tract of mined land for agriculture depends to some degree on the proximity to established farming operations and the topography of the disturbed area; but, it is even more dependent on the characteristics of the spoil material. Spoil from limestone and lime-bearing shale overburden often can be reclaimed with relatively little cost and within a few years. Occasionally, this kind of spoil contains generous amounts of plant available phosphorus, potassium, and other elements essential to plant growth. Usually, the pH varies from about 6.0 to 8.0 and the spoils contain relatively few coarse fragments or stones. Planned mining and especially planned back-filling is usually necessary to prepare spoil for agricultural uses.

Spoils from acid sandstone and shale overburden seldom make good areas for agricultural use unless much time and expense are involved in correcting the acid situation. Even then, the production may not be worth the expenditure and trouble of repeated ameliorative treatments.

The most common agricultural use of reclaimed spoil is pasture and hayland. Generally, most of the forage grasses and legumes adapted to a

geographic area will produce satisfactory yields on the spoils suited to agriculture. Nitrogen and phosphorus fertilizer will usually hasten establishment of the forage plants. If the spoils contain adequate plant-available phosphorus, further fertilization may not be needed, especially if the stand of forage contains a favorable balance of legumes. However, the need for maintenance fertilization can best be learned from experience and perhaps with the aid of soil fertility tests.

For establishing pasture or any agricultural use on spoils more acid than pH of 6.0, applications of lime will normally be required to reduce the acidity. If the spoils are strongly to extremely acid, applications of lime may be required on a yearly or other regular schedule. But, let's repeat, if spoils are that acid they should probably not even be considered for agricultural use.

The chemical and physical makeup of some spoils is so favorable that, after a few years of growing grasses and legumes, the areas can be tilled and planted to crops such as wheat, oats, corn, or sorghum. Usually greater amounts of fertilizer, especially nitrogen, are required for producing satisfactory yields of grain on spoils than on soil. Orchards are another agricultural use that have been and can be developed on spoils with favorable chemical and physical properties.

When establishing the initial forage crop on spoil there is perhaps one advantage over establishing them on normal farm land--there is little

or no competition from weeds if the seedings are made as soon as possible after grading is completed. Thus, in many cases, a grass or legume could be grown for certified seed production because the field would be nearly weed free. This would be true especially on some of the mine benches in the mountainous regions, because the source of contaminating weed seed is not so great as in agricultural areas. However, in most of these mountainous, non-agricultural areas there is no harvesting equipment available locally for harvesting the grass or legume seed.

Lakes and Recreation

Some strip-mined areas have been reclaimed and developed for recreational use. Sites suitable for intensive recreation development such as golf courses and parks are very limited in Appalachia, but there are some strip mines that can be used for campsites, picnic areas, ponds, and lakes.

Areas developed for recreational use should be near population centers and readily accessible. These factors are very important in attracting users to the facility.

Most recreational enterprises and facilities must be laid out and installed according to a design or plan. They usually have specific site requirements. The area must be large enough and restored or graded to meet the necessary topographic requirements.

In order to develop ponds and lakes on strip-mined areas, the water must meet certain standards. The surrounding spoil must be suitable for

vegetation. The construction of impoundments and water-related recreational facilities should also be included in the reclamation plan.

Where topography is favorable, and where acid-forming material is not extensive enough to make the water toxic, strip-mine impoundments may be stocked with fish.

The long, narrow contour strips in mountainous country offer a variety of possibilities for campgrounds, scenic overlooks, or trails for travel by jeeps, motorcycles, and horses.

An important consideration in developing strip-mined areas for recreational uses is the elimination of health and safety hazards. Roads and trails should not be located near steep highwalls or cliffs; vertical or steep bank ponds and lakes should be avoided or adequate protection provided.

A recreation development plan should be prepared for any area before work is begun. This will give the landowner a chance to determine the economic practicability of the development before it is undertaken. Recreational development may be quite expensive and may take years to accomplish, but possibility of a successful venture should not be overlooked.

Sanitary Fill

Strip-mined areas are well suited to sanitary fills because they are accessible to heavy trucks and have abundant loose spoil to cover refuse. Many towns and small rural communities in Appalachia use mined areas for refuse disposal, but much of the dumping is handled in a haphazard manner.

With advance planning, contour strip mines can be developed for sanitary fill areas at little or no additional cost. Pit areas can be left open or only lightly covered to leave maximum storage space. As a small section of the pit is filled with refuse, several feet of spoil should be pushed on top. By starting at one end of a strip mine and covering the refuse as you go, a gently graded bench can be developed in an orderly manner.

Drainage control in sanitary fills is essential. Disposal areas should not be located near streams or where groundwater can be contaminated. Spoil material used for covering refuse should be gently sloped so that water drains away from the fill area.

Here again, it is necessary to maintain access roads. Local health and safety laws should be checked. Pennsylvania, for instance, has extensive regulations governing the use of strip mines for sanitary fill.

Housing and Industrial Sites

In much of Appalachia, level land for housing and industrial development is at a premium. Comparatively level land created by reclaiming strip-mined areas can be used for these purposes. Location of mined areas in relation to population centers, utilities, and transportation systems is the primary limiting factor.

Area-type stripping is more easily developed for industrial sites because it occurs in large blocks. Adequate water supply need not be a

problem if a lake is constructed as part of the reclamation plan. Spoil should be graded to the desired shape, drained well, and allowed to settle. Supports for heavy buildings may have to extend to solid rock strata below the spoil.

Contour strip mines can be developed into housing sites. First, the spoil material must be allowed to settle and stabilize. Houses and access roads should be constructed over the solid rock bench for stability and safety. However, houses should be placed away from the highwall to avoid damage from any rocks which may work loose. Spoil can be easily shaped for landscaping, but it may be desirable to apply a shallow covering of soil to establish smooth, rock-free lawns. The loose spoil offers possibilities for burying utility lines.

RECLAMATION OF ABANDONED OR ORPHAN AREAS

There are many areas throughout Appalachia that were mined before enactment of any effective laws. These sites are either unreclaimed or only partially restored. Add to these areas portions of mined land reclaimed under modern laws but not meeting minimum standards of basic reclamation, and the total mined area needing reclamation becomes quite large. Mining operators have long since been released from responsibility; thus these areas will probably have to be restored at public expense.

Techniques for restoring abandoned areas are no different from basic reclamation methods as outlined in previous sections. Because reclamation

was not completed by the operator, work on abandoned areas is usually handled by separate bids and presents special administrative problems. If public funds are used, what portion of the cost, if any, should the land owner bear? Or should the land be purchased by the state, reclaimed, and then sold at public auction?

Before any action program, a survey must be made to determine the extent and condition of abandoned areas. Reclamation needs for each site should be noted, including drainage and erosion control, grading, revegetation, and repairing slide damage. Preferably all areas disturbed by mining should be included in the survey. In addition, an updating system is needed to keep information on mining and reclamation current.

Once a survey is completed, information should be summarized and priorities assigned to each area needing additional reclamation. It is unlikely that funds sufficient for all areas will become available at one time; and even so, it would take several years to reclaim all abandoned areas in a major coal-producing state. Areas causing the most serious water pollution problems or creating safety hazards should be reclaimed first. Other factors that should be considered are cost, availability of equipment or contractors, and proximity to areas of high aesthetic value.

RECOMMENDATIONS FOR APPLYING RECLAMATION TECHNIQUES AND DEVELOPING IMPROVED METHODS

Although much progress has been made, many problems remain to be solved. The major one of these is the sediment and chemical pollution of streams. A better job must be done in applying on the ground techniques that have been proved effective by research and practice. And research must help the operators and regulatory agencies by developing solutions to the problems as yet unsolved.

Applying Known Techniques

Strip-mine reclamation is a relatively new art. Partly for this reason, there is a greater-than-average need for education and training of the people involved--including those doing the work and those in the regulating agencies. This applies across the board to all phases from planning prior to mining to post-mining reclamation. There are, however, a number of areas of specific need.

In the Planning Stage

Planning prior to the operation should, but usually does not, include consideration of the most probable future use or uses of the area. Preferably, planning for the mined area should be part of an overall plan for the general area.

More detailed plans are needed than those currently prepared in most cases. Variation in site requirements over short distances makes this necessary. And reclamation methods and objectives should be thoroughly covered.

Better on-the-ground exploration is needed. In many cases this may require core drilling. Only if the operator knows the amount and value of the coal, the amount and character of overburden (including the toxicity of the different strata)--only then can he make sound plans for mining and reclamation.

More of the impact of strip mining is caused by haul and access roads than has been generally recognized. The plan must give as serious consideration to roads as to other phases of the operation. In preparing the plan, an on-the-ground look at conditions and problems is needed in addition to map and aerial photograph study.

During the Mining Operation

The mining operation should be more flexible. Changes in conditions along the strip should be recognized and modifications made in spoil handling and other techniques where appropriate.

A better job must be done in separating toxic and non-toxic spoils. Though color and toxicity are sometimes related, it must be recognized that separation cannot be based on color alone. Better identification here will be facilitated by analyses of strata in the planning stage.

Drainage of water from the operation can be improved. Water must be drained away without causing excessive erosion and in low, relatively steady discharges rather than violent slugs. Suggestions have already been made in this report on how this can be done.

During Reclamation

A better job of reclamation can be done if the probable future use receives more attention during the planning phase and during conduct of the work.

The burying of toxic materials--and the placing of favorable materials on the surface--can be improved. This can be accomplished through practice and upgrading the priority of this activity. As in the mining stage, color alone is not enough to guide separation.

A better job can be done in draining water from the bench through selection of discharge points and protection of the outslope from erosion. The construction of sediment impoundments in streams below the strip-mine operations must become a more common practice than at present.

A protective cover of grasses and legumes can be established faster if closer attention is paid to spoil fertility and seedbed requirements.

And a program is needed to reclaim any abandoned or orphaned areas which are damaging the environment.

Research Needs

Improved knowledge of the magnitude and characteristics of any problem is fundamental to improved measures to meet the problem. A state-by-state survey of mining operations and reclamation needs should be conducted. Where reclamation has been inadequate, the cause--whether it be failure to apply known methods or the lack of available adequate methods--should be determined.

Sociologic and economic studies should be made to determine the impact of strip mining and reclamation on people. Public attitudes toward reclamation should also be studied--what is considered adequate reclamation and what types are preferred.

Research is also needed on the reclamation job itself, as discussed below.

In the Planning Stage

Relationships between the chemistry of overburden strata to spoil characteristics must be investigated to provide operators with the information necessary to segregate different spoil materials.

During the Mining Operation

Improved mining techniques and perhaps modified or new equipment must be developed for separating and handling spoils.

Techniques must be developed for more efficient identification of noxious spoils--and this identification must of course be made long before the vegetation establishment phase is reached.

Design criteria are needed for sediment impoundments in streams below the operation. Treatments for removing acids and chemicals from polluted waters before they reach major streams should be investigated. It may be necessary to develop portable water-treatment equipment suited to strip-mine operations.

The problems of noise and dust need to be recognized, investigated, and methods devised for control. In this regard, the dust problem on mining roads should not be overlooked.

During Reclamation

Drainage onto, over, through, and from strip-mine spoils is at the root of many if not most of the problems of these areas. Basic understanding of infiltration and percolation over the variety of conditions encountered must be improved. A basis for deciding when infiltration and percolation should be encouraged or when they should be prevented must be developed. This involves study of the quality of groundwater from spoil banks as well as many other factors. Techniques for leading water from the benches to natural stream channels must be improved. An understanding of drainage processes is a prerequisite to designing better methods of spoil disposition and landform shaping.

Criteria must be developed on when and how to create ponds and lakes. Benefits and hazards under a variety of conditions must be investigated and evaluated.

Methods for preventing the occurrence of slides must be developed. This problem is intricately tied in with drainage problems, methods of spoil disposition, etc.

Different methods of spoil disposal and site grading must be studied in depth. When and how to use methods such as valley fill, rolling grade on the mountaintop, slope reduction of outslopes, and regrading to original contour must be determined. Drainage problems, such as the breaking of long slopes, are intimately associated here. And modification of techniques must be developed in order to make possible a better overall reclamation job.

Many revegetation problems remain unsolved and must be investigated. These include toxic spoils, steep outslopes, and direct seeding of trees and shrubs. The role that soil fauna and microorganisms play in soil development and plant growth should be studied. And many problems of vegetation establishment on deep-mine spoils remain to be solved.